The Relation between Executive Function and Motivational Orientations via Private Speech in Preschoolers

by

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Hon. B.Sc., University of Toronto, 2002
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Abstract

Language may play a key role in determining the relation between motivation and higher-order cognitive processes, as language has been shown to have a motivational function in preschoolers (Chiu & Alexander, 2000) and has also been implicated in the development of executive functioning (Hughes & Graham, 2002). The particular aspect of language which may best serve to connect these processes is self-directed speech (i.e., private speech) as the production of private speech is an indication of language and thought merging to form a new level of cognitive organization (Berk, 1992; Chiu & Alexander, 2000). Determining if the relation between motivational orientations and executive functioning can be mediated by private speech was examined to provide insight into the way in which motivational orientations and cognitive skills are related.

In order to explore the role of private speech as a mediator, 4- to 6-year-old children were administered two EF tasks, the Tinkertoy test and the Tower of Hanoi, during which the impact of various reward contingencies on EF performance and self-directed speech elicitation was investigated. Although relations were found between measures of motivation, private speech, and EF performance, private speech did not act as a generative mechanism through which motivation influenced children's performance on the EF tasks. This study represents the first attempt to explore such a mediational model in this age group and results provide preliminary information about how private speech, motivation, and EF are related with regard to children's goal directed behaviors.

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1. Introduction

Over the past few decades a “social-cognitive” approach to the study of motivation and self-regulation has emerged. The social-cognitive approach is built around goals and goal-oriented behavior and attempts to identify the specific psychological processes that shape our actions (Heckhausen & Dweck, 1998). A distinctive feature of this approach is the attribution of a role to orientations that are motivational in nature with respect to the development of cognition, emotion, and behavior. These motivational orientations serve as indicators of why individuals strive to succeed at particular goals, describing the driving force behind people’s actions. Accordingly, the social-cognitive approach provides an opportunity to explore how motivational orientations influence other well studied psychological processes, such as executive functioning, as children strive to achieve certain goals via intentional actions (Dweck & Leggett, 1988; Heckhausen & Dweck, 1998). Defined as the ability to control, inhibit, and monitor one’s own activities (Russell, 1996), executive functioning (EF) can be viewed as an umbrella term that captures various inter-related processes necessary for goal-directed behavior (e.g., planning; Anderson, 2002; Gioia, Isquith, & Guy, 2001).

Within the social-cognitive approach, some researchers have suggested that language plays a key role in determining the specific relations between processes involved in the development of goal-directed behaviors such as motivational orientations and higher-order cognitive functions (i.e., executive functioning). Language has been shown to have a motivational function in preschoolers when working on age appropriate challenging tasks (Chiu & Alexander, 2000). The importance of language has also been implicated in the development of executive functioning as “developmental improvements in executive function are fundamentally entwined with developmental increases in language ability" (Hughes & Graham, 2002, p.134). The particular type of language which may best serve to connect these processes is self-directed speech (i.e., private speech). The use of private speech is an indication of language and thought merging to form a new level of cognitive organization (Berk, 1992; Chiu & Alexander, 2000). According to Vygotsky (1934/1986) a pivotal milestone in cognitive development is attained when language is not only used for communication with others, but also as a tool to direct one's own thoughts and behaviors (Chiu & Alexander, 2000). At first, this type of self-regulation is overt and seen through the use of private speech, which then becomes internalized as inner speech. Consequently, as private speech is related to both EF and motivational orientations, it may influence the relation between these constructs.

The present study examines whether language, and in particular private speech, plays a role in determining the ways in which motivational processes and EF are related with regards to children's goal-directed behaviors. Specifically, the relations between motivational orientations, the amount and type private speech produced, and EF skills will be explored in preschool children. The study will focus on the preschool period as it is during this period that major changes in EF abilities (Zelazo, Carter, Reznick, & Frye, 1997), motivational orientations (Dichter-Blancher, Busch-Rossnagel, & Knauf-Jensen, 1997) and the elicitation of private speech occur (Manning, White, & Daugherty, 1994).

The introduction is structured as follows: The first section describes the proposed model in which the relation between motivational orientations and EF is influenced by the production of self-directed speech. The second section of the paper discusses motivational orientations including investigations of their relation to self-directed speech. Following this is a review of executive function and its relation to motivation. The next section addresses the relation between self-regulation and private speech and describes the functional nature of private speech. Then, I will suggest how private speech is implicated in the development of both motivational orientations and EF. The final section provides the rationale, research design, and methodology of the study.

1.1 The relation between motivational orientations and cognitive development

Though not empirically investigated, several authors have anecdotally suggested that there is a developmental association between motivation and EF. Hunt (1965), the first of such authors, described motivational orientations in relation to cognition and proposed a reciprocal relation between mastery motivations and the development of cognition. Harter (1975) introduced a model of mastery motivations that also intimates a reciprocal relation as it suggests that children's behavior is determined by a motivational system involving both mastery motivation and cognitive competence. Zelazo and Müller's (2002) "hot" and "cool" framework of EF proposed an association between EF and motivation. When "hot" EF is elicited the individual is thought to be invested in and concerned with the task at hand due to the presence of an external reward (Zelazo, Qu, & Müller, 2005). Such a link could be interpreted as attributing a role to extrinsic motivation in the development of "hot" EF, with an individual performing an activity, in part, in order to receive a desired consequence. This too would suggest that cognition and motivational orientations operate concurrently and that one does not necessarily precede the other in the course of development. Further, Chiu and Alexander (2000) argue that it is unknown whether cognition is a prerequisite for motivation or that motivations facilitate cognition, thus suggesting that a reciprocal relation may indeed exist. Thus, there is a lack of precise knowledge concerning the type of relation that exists between these psychological processes. As numerous researchers have put forth the suggestion that in fact a relation does exist, a plausible next step is an empirical investigation examining the precise nature of the relation.

During toddlerhood and the preschool years there is a gradual shift from children's behavior being externally controlled by others to being internally controlled

(Winsler, Diaz, Atencio, McCarthy, & Chabay, 2000). This process of internalization is emphasized as the primary mechanism for developmental change in numerous theories of the development of self-regulation (e.g., socialization, psychodynamic and Vygotskian/sociocultural theory; Winsler et al., 2000). Vygotskian theory specifies that it is language which is being internalized and acts as the mediating link in the transition from other- to self-regulation. Interestingly, both motivational orientations (e.g., Harris, Robinson, Chang, & Burns, 2007) and EF (e.g., Bodrova & Leung, 2006) have also been implied in the development of self-regulation.

In reviewing research regarding private speech in relation to both motivational orientations and cognitive skills, it is apparent that language, and in particular self-directed speech, should be considered an integral process in elucidating the role motivational orientations play in the development of the regulation of cognition. Specifically, as a metacognitive ability, private speech may help to explain how specific motivational orientations contribute to successful self-regulated learning of cognitive skills such as those implied in the term executive function and vice versa. A systematic investigation into these relations would fill a void in the literature as it brings together two types of processes (i.e., motivational orientations and executive functioning) which are usually studied independently of each other.

The primary goal of such an undertaking would be to test the general hypothesis that motivational orientations, executive function, and private speech are indeed related. Previous empirical studies reporting significant correlations between private speech and motivation in children did not clarify whether private speech motivates children or motivation leads children to express private speech. The development of language, including self-directed speech, however, is thought to mediate the development of conscious executive control (Zelazo, 1999, 2000). Based on these suggestions, investigating how the relation between motivational orientations and EF can mediated by private speech is warranted, and would provide insight into the way in which motivational orientations and cognitive skills are related.

A mediational model would suggest that private speech elicitation acts as a generative mechanism through which motivational orientations influence performance on an EF task. This model, however, would also take into account the direct impact motivational orientations may have on EF performance. Thus, testing the mediating effect of private speech would enrich the understanding of the processes involved in motivational orientations and EF tasks within development. Figure 1 illustrates the framework for the proposed mediational model and will be used as a basis to describe the hypotheses to be tested in pursuit of the study's primary goal. The framework has three main causal paths, each representing the distinct hypotheses to be tested: (1) The effect of motivational orientations on private speech elicitation (path B), (2) the effect of private speech elicitation on EF performance (path C), and (3) the direct effect of motivational orientations on executive function performance (path D). The following sections discuss the three variables involved in the model, followed by an overview of research in support of model's three main causal paths.

1.2. Motivation

1.2.1. Motivational orientations

Ryan and Connell (1989) suggest that it is not only important to distinguish between the level and degree of strength of an individual's [achievement] motivations, but also to distinguish motivational strengths in terms of each individual's orientation toward that energy (Ryan, Connell, & Grolnick 1992). The reasoning and importance behind making this distinction is that it is necessary to not only understand how strongly people are motivated to achieve something, but also why they strive to succeed. Initially, previous work had focused on the level of achievement. It is only more recently that orientation has become a focus of research (Ryan et al., 1992). Additionally, some work centered on determining why, when pursuing a different task, different individuals may be oriented to different types of goals (Cervone, Mor, Orom, Shadel, & Scott, 2004). Some researchers pursuing this line of work have explained orientations in terms of two patterns of emotions, cognition, and performance that children display when confronted with a challenging task: (1) mastery motivation and (2) performance motivation (Cain & Dweck, 1995; Dweck, 1998). A different line of research focuses on the nature of the driving force behind the pursuit of goals. These studies examined why individuals who are pursuing goals are more externally versus internally motivated (e.g., Deci & Ryan, 2000). Each of these views regarding orientations will now be discussed in turn.

1.2.2. Mastery motivation vs. performance motivation

The construct of mastery motivation refers to a pattern of cognitive-affective-behavior that has received considerable attention in the field of motivation. Mastery motivation is described as a core concept of development (Schonkoff & Phillips, 2000) and "…is characterized by persistence in challenging situations, maintenance of positive affect, and expressed interested in control of the environment" (Harris, Robinson, Chang, & Burns, 2007, p. 27). In general, researchers examining mastery motivation are interested in children's exploration, curiosity, and effort to achieve (Chiu & Alexander, 2000). For example, some researchers' goals have been to determine why children may easily be discouraged when faced with a demanding task and while others persist (e.g., Smiley & Dweck, 1994). Whereas other researchers have focused on why some children prefer a challenging task and persist more at completing them rather than giving up (e.g., Harter, 1978).

Various factors may be responsible for the fact that children develop different patterns of motivation. A first possibility is that children are concerned about the feedback that they receive from others, especially from authority figures. That is, they have performance-oriented goals because they are concerned with being perceived as smart and have a desire to please others (Chang & Burns, 2005; Smiley & Dweck, 1994). A second possible factor is the type of critical feedback they receive from parent and teachers. Different motivational patterns may develop depending on whether the feedback is referring to attributes of the child or to the child's effort or behavior (Kamins & Dweck, 1999). For example, more helpless behavior is seen after receiving personal praise or criticism compared to when process praise or criticism is given (Chang & Burns, 2005). A third possible factor related to the development of motivational orientations is children's belief about their worth as a person (Burhans & Dweck, 1995). Children may develop a helpless pattern if they feel their worth is contingent upon their performance and they receive negative feedback. For example, Heyman, Dweck and Cain (1992) found that some children interpreted criticism to mean that they were bad people, while other children did not view the criticism in this way.

Initially, differential patterns of motivation were thought to develop after age 10, as it was believed that children did not show much negativity when confronted with failure before this age (Smiley & Dweck, 1994). However, research from the early 1990's by Dweck and colleagues showed that even preschoolers display different patterns of motivation. This therefore raised the important question of when mastery motivation develops, as the answer has implications for when in development and how the construct is assessed. In infancy, the development of mastery motivation has been characterized by 3 phases, with transitional periods of change between each phase (Dichter-Blancher, Busch-Rossnagel, & Knauf-Jensen, 1997). The first phase, which occurs from birth to 8-9 months, is characterized by a preference for novelty. In the second phase, which occurs between the ages of 8-9 months and 17-22 months, children gain the ability to control outcomes. The third phase, which lasts until 36 months, involves increases in the ability to complete multipart tasks (Barrett & Morgan, 1995). Despite evidence of mastery motivation in infancy, the majority of recent research on young children's mastery motivation focuses on older children due to the lack of adequate measures for use with infants.

In toddlers, mastery motivation can be assessed through observation of free play, by maternal report, or by using structured tasks (Dichter-Blancher, Busch-Rossnagel, & Knauf-Jensen, 1997). Examples of structured tasks include problem solving tasks such as puzzles, mazes, shape-sorters, and cause-and-effect toys (Harter, 1975; Dichter-Blancher, Busch-Rossnagel, & Knauf-Jensen, 1997). The use of structured tasks allows for the assessment of various behavioral indicators of mastery motivation: (1) children's preference for a challenging version of a task versus a less challenging one (e.g., Smiley & Dweck, 1994); (2) children's display of pleasure of mastery when completing a challenging task (e.g., Redding, Morgan, & Harmon, 1988); (3) the amount of time children persist at a challenging task (e.g., Kelley, Brownell, & Campbell, 2000); (4) free-choice-period persistence (i.e., engagement) in a difficult task; (5) self-reports of affect (e.g., Joussemet, Koestner, Lekes, & Houlfort, 2004); and (6) by children's curiosity as measured by the amount of time children spend exploring and manipulating objects (e.g., Jennings, Connors, & Stegman, 1988).

Using problem solving tasks, Harter (1975) was one of the first researchers to describe the differences in the mastery motivation of 4-year-old and 10-year-old children. The apparatus used to assess mastery motivation was a cause-and-effect toy in the form of an automated box with two Plexiglas disks that could be lit in red and green, and a tray into which marbles were dispensed (Harter, 1975). Pushing one of the two disks caused the lights to turn off, and a marble was released for correct responses. Either a solvable color discrimination problem (i.e., reward paired with a particular color) or an unsolvable discrimination problem (i.e., reward was randomly paired with color) were presented to participants. Harter found that 4-year-old children displayed a type of mastery motivation that involved the repeated production and observation of interesting sensory events that they could control through their own actions. Preschoolers did not stop playing the solvable task once they reached the goal criterion. They continued to press the illuminated disks and appeared to have no investment in correctness. Such findings differ from the type of mastery motivation of 10-year-olds, which involves placing emphasis on the discovery and correct solution to the problem. The difference in development appears to lie in the nature of the behaviors: repeated production of an interesting stimulus event versus cognitive ability to predict and produce the correct response. According to Harter (1975), both mastery motivation and approval appear to be important determinants for development: as a result of efforts to behave in a manner that will elicit approval, the child gradually develops and internalizes a self-reward system that is consistent with the values of the social environment. That is, while an adult's approval has a significant role in determining children's behavior, it is eventually replaced by a motivational system involving mastery and cognitive competence (Harter, 1975).

1.2.3. Intrinsic and extrinsic motivation

Motivational orientations need not only be used to describe the different patterns of behaviors adopted by individual's when faced with a challenging task, but may instead serve to explain whether an individual is driven to perform a task based on their own intrinsic desires or by external forces. Intrinsic motivation drives individuals to perform activities for their own self and pleasure is thought to be inherent in the activity itself (Deci, 1975; Gottfried, Fleming, & Gottfried, 1998). According to Deci (1975), intrinsic motivation is derived from the need to feel competent and self-determined. Intrinsic motivation refers to the active engagement in tasks that individuals find interesting and promotes self growth. The sustainability of this engagement, however, is grounded in the satisfaction of the psychological needs of competence and autonomy (Deci & Ryan, 2000). Extrinsic motivation, by contrast, refers to "activity that is more directly instrumental” and is based on “people’s needs to respond to socially prescribed demands, limits, and patterns of behavior” (Ryan, Connell, & Grolnick, 1992, p. 170). For example, individuals behave in a specific manner in order to obtain a desired consequence (e.g., tangible reward such as a good grade) or to avoid a threatened punishment (Deci & Ryan, 2000; Ryan et al., 1992).

When extrinsic motives are completely external or removed from the person the activity becomes externally regulated. There are, however, other types of behaviors that are driven by extrinsic motives despite there not being any directly apparent external rewards. These are introjected, identified, and integrated regulation. The variation between the different forms of extrinsic motivation can be described via internalization, a process in which individuals progressively transform initially acquired beliefs and behaviors from external sources into personally endorsed values and self-regulations (Deci & Ryan, 2000; Ryan et al., 1992). An example of introjected regulation would be a child who performs well academically to gain real or projected approval of a teacher. Here, the child is not learning solely for personal benefit or for a tangible external reward, but the reward is considered somewhat external. Identified regulation would characterize children who strive to achieve because they value learning and they identify with the value of doing well in school. The reward is therefore considered, to a degree, internalized. Integrated regulation is considered “the most complete form of internalized extrinsic motivation” (Deci & Ryan, 2000, p. 236), as it involves both identifying the importance of certain behaviors and their integration with other aspects of one’s self. The internalization of motives from external regulation to intrinsic regulation is conceptualized on a self-determination continuum which describes the degree to which the motives are the least (i.e., controlled) to highly internalized (i.e., autonomous). The process of internalization represents a movement away from control from external forces towards the self-determination of one’s own behaviors (i.e., autonomous; Ryan et al., 1992).

Researchers use the above distinctions between levels of motivation to determine an individual’s self-concordance with certain goals (e.g., Deci & Ryan, 2000; Sheldon & Houser-Marko, 2001). Self-concordance refers to the degree to which a goal reflects the personal interest and values of an individual (Koestner, Lekes, Powers, & Chicoine, 2002). Self-concordance is assessed by asking participants to rate the reasons for which they are pursuing a goal based on the four different types of regulation that fall on the self-determination continuum ranging from highly controlled to highly autonomous (Koestner et al., 2002): external (e.g., because some else is telling you to); introjected (e.g., because you would feel guilty if you did not do so); identified (e.g., because you believe it is an important goal); and intrinsic (e.g., because of the satisfaction the goal will provide). Self-concordance is calculated by summing the intrinsic and identified ratings and subtracting the introjected and external ratings.

To determine which factors facilitate or impede internalization, researchers have studied the effects of extrinsic rewards as motivational strategies on children’s involvement in a given activity (Ryan & Deci, 2000). For example, Joussemet, Koestner, Lekes, and Houlfort (2004) studied the effect of rewards on children’s self-regulation for an uninteresting task by examining children’s ratings of positive affect and perceptions of task value, as well as free-choice engagement in the task. In the reward condition, the “relation between behavior and feelings about the task was found to be negative” (Joussemet et al., 2004, p. 151). Therefore, internalization was found to be introjected due to the negative correlations found between free-choice behavior and both self-report variables (i.e., affect and task value) in the reward condition versus the no-reward condition (Deci & Ryan, 2000). A meta-analysis by Deci, Koestner, and Ryan (1999) shows that all tangible rewards which are contingent on task performance undermine intrinsic motivation as the rewards facilitate an externally perceived locus of causality.

1.2.4. Relations between motivational orientations

Can relations be found between the above two descriptions of motivational orientations? Upon first examination, it would appear that the term “motivational orientation” is being interpreted in two distinct manners: one group of researchers views the term as a description of how individuals approach tasks, whereas the second group interprets it as the driving force behind an individual pursuit of a goal. Upon closer inspection, however, it becomes apparent that these two points of view may, in fact, bear some similarities to each other. When examining the description of adaptive mastery-oriented patterns of behavior (i.e., the pursuit of challenging tasks in order to learn and hone skills), the definition of motivational orientation can be construed as connoting that children are pursuing tasks for intrinsic reasons. On the other hand, maladaptive performance-oriented behavior patterns (i.e., avoidance of challenging tasks in order to demonstrate abilities rather then risk failure) can be labeled as extrinsic in nature as children are striving to please an authority figure when showing off their skills. Analogies can be drawn between learning and performance goals to intrinsic and extrinsic motivation. As with the mastery-oriented behavior patterns, learning goals can be viewed as intrinsic in nature as they involve an internalized need to increase one’s competence. Performance goals are similar to performance-oriented behavior patterns as they also involve gaining positive feedback from an authority figure regarding competence, and therefore are driven by an external (i.e., extrinsic) force.

Empirical evidence supporting the above relations can been found in studies with elementary school children. The use of controlling strategies (e.g., rewards) by teachers produces extrinsic orientations in students, which are associated with lowered subsequent intrinsic motivation, decreased mastery strivings, and impaired problem solving skills (Boggiano, Main, & Katz, 1988, 1991; Deci & Ryan, 1985, 1987). When comparing children with controlling teachers to those with teachers who promote autonomy, students exposed to the former developed an extrinsic motivational orientation and report perceptions of lower competence and decrease mastery strivings compared to intrinsically motivated students (i.e., those with autonomy promoting teachers; Deci, Nezlek, & Sheinman, 1981).

Despite these distinctions between different types of motivational orientations, connections may also be found. According to Cognitive Evaluation Theory (CET; Deci & Ryan, 1985), intrinsic and extrinsic motivations are developed through an individual's self-evaluations of their competence. Therefore, the use of autonomy supportive techniques permits a sense of competence to be satisfied, which facilitates the development of intrinsic motivation.

The diathesis-stress model of achievement processes (Boggiano, 1998) proposes two complementary but distinct models in which intrinsic motivation temporally precedes maladaptive behaviors. First, a mediational model posits that an intrinsic motivational orientation engenders adaptive achievement pattern that include higher mastery pursuits and higher perceptions of competence. Alternatively, a moderational model views an intrinsic motivational orientation as more stable and these motivational orientations act as a buffer with respect to the effect of controlling strategies on children's competence and maladaptive behaviors. The latter model proposes that intrinsic motivational orientations (and not extrinsic ones) "immunize" children's from the adverse effects of teachers' use of controlling strategies (Guay, Boggiano, & Vallerand, 2001).

While an individual's goal orientations may be discussed in terms of why individuals pursue certain goals or the effects of being more internally or externally driven to pursue a goal, the evidence presented demonstrates that both types of orientations may influence each other to some degree and play a role in an individual's ultimate success or failure at achieving their goals. In the present study, only intrinsic and extrinsic motivation will be examined when assessing the relation between motivational orientations and cognitive skills. However, as both types of motivational orientations influence each other, the findings of the present study will have implications regarding a relation between why individuals pursue goals and their cognitive abilities.

1.2.5. The effect of rewards on motivational orientations

Parents and teachers frequently rely on extrinsic tangible rewards in order to teach valued behaviors or elicit desirable conduct. The use of rewards as incentives to improve children's performance has been met with controversy (Carmeron, Pierce, Banko, & Gear, 2005). There are those who argue that rewards are detrimental (e.g., Deci, Koestner, & Ryan, 1999), while others claim that rewards can be used to increase motivation and performance (e.g., Cameron, 2001). This debate has evolved from questioning whether rewards are beneficial or harmful to now recognizing that the effect a reward has depends on the types of rewards used, the reward contingency, and the context in which the reward is given (Cameron et al., 2005).

Many studies have been conducted to investigate the effect of rewards on intrinsic motivation. Typically, participants are presented with an interesting task (e.g., a puzzle) and are either offered a reward for doing the task (i.e., experimental condition) or engage in the activity without being told they will receive a reward (i.e., control condition). All participants are then observed in a free-choice period without a reward in which they are free to continue performing the same activity or a different one. Originally, the primary measure of intrinsic motivation was thought to be the degree to which participants return to and persist at the original activity (Deci, 1975). Today, measures of intrinsic motivation include the time participants spent on the original task during the free-choice period, performance on the task during the free-choice period, and ratings of task interest (Cameron, Pierce, Banko, & Gear, 2005). When results of these studies were aggregated meta-analytically (Deci, Koestner, & Ryan, 1999), the effects of extrinsic rewards are "clear and consistent" (p. 653). The negative effect of tangible rewards on intrinsic motivation for interesting tasks was present in preschool through college age participants. However, rewards that were performance-contingent (e.g., rewards linked to an individual's performance) did not influence self-reports of interest in the task at hand compared to rewards that were engagement- or completion-contingent. Performance-contingent rewards are considered the most complex type of tangible reward as they may convey positive information about an individual's competence (e.g., individual performs well enough to receive reward which represents excellence), but are also very controlling (i.e., individuals need to meet standard to maximize rewards, Deci et al., 1999). The meta-analyses also identified conditions under which rewards can be used to maintain or enhance intrinsic motivation for interesting tasks: when participants are verbally praised for their work, when rewards are presented in an informal manner, when rewards signify competence at the task, and when rewards are presented when participants achieve certain standards. In the present study, children's intrinsic motivational orientations towards a task are manipulated through the use of an external reward.

1.3. Executive functioning

The collective of cognitive processes referred to as executive functions are a prominent aspect in studying the development of self-regulation (Blair & Razza, 2007), as the development of executive functioning is widely believed to play an important role in self-regulation (Blair, 2002; Bodrova & Leung, 2006; Bronson, 2000a). This is mostly due to the fact that the primary focus of EF is on the volitional control of cognitive self-regulatory processes (Blair & Razza, 2007). Generally, the term EF refers to the mental operations involved in the conscious control of thoughts and actions (Baddeley, 1996;

Perner & Lang, 1999; Stuss & Knight, 2002; Zelazo & Müller, 2002). This type of conscious control is required when one encounters a novel situation and must, in turn, generate a response that is in conflict with automatic response tendencies (Riggs, Blair, & Greenberg, 2003). For example, EF is often used to describe cognitive processes involved in tasks necessitating the inhibition of certain behaviors, such as the disengagement from prepotent aspects of a problem and engagement in less perceptually salient aspects.

Research on the development of EF has established certain key facts: (a) EF most likely emerges around the end of the first year, (b) important changes occur between 2 and 5 years of age, and (c) EF continues to develop across a wide range of ages with adult-level performance being reached by about 12 years of age on most tasks (Davidson, Amso, Anderson, Diamond, 2006; Garon, Bryson, & Smith, 2008; Huizinga & van der Molen, 2007; Zelazo & Müller, 2002). Much discussion has transpired as to how to properly define EF, as several different approaches to EF can be found within the literature. Some approaches are so broad that they claim that EF can be defined as a heterogeneous list of abilities (e.g., Levin et al., 1991). Others place emphasis on one particular aspect of EF, and explain various deficits in terms of a particular function such as inhibition (e.g., Barkley, 1997; Carlson, Moses, & Hix, 1998; Dempster, 1992) or working memory (e.g., Kimberg, D'Esposito, & Farah, 1997). Such a unified description of EF can not adequately characterize the manner in which EF is a result of the interaction of complex metacognitive and strategic processes (Zelazo, Carter, Reznick, & Frye, 1997; Zelazo & Müller, 2002). What these approaches fail to recognize is that each of the processes implicated in EF may in fact belong to a coherent (and likely complex) family of processes (Zelazo et al., 1997).

The term EF is most often described as a domain-general cognitive function (e.g., Zelazo, Cater, Reznick, & Frye, 1997; Hongwanishkul, Happaney, Lee, & Zelazo, 2005), representing how we come to control our thoughts and behaviors when solving problems in a wide variety of content domains. Viewing EF as a domain-general cognitive function originated from Luria's (1973) suggestion that neurological systems, such as the prefrontal cortex (PFC), consist of interactive functional systems which involve the integration of subsystems. These subsystems have a specific role to play, but must be considered within the larger system to which they belong (Garon, Bryson, & Smith, 2008; Zelazo & Müller, 2002). This suggests a way in which to capture the diverse processes involved in EF that does not involve listing them or evoking a homunculus (Zelazo, Qu, & Müller, 2005).

Although it has been widely accepted that executive functioning can be understood as a domain-general construct (i.e., as conscious goal-directed problem solving; Zelazo, Carter, Reznick, & Frye, 1997), recent research on specific areas of the PFC implicates different areas in relation to different functions, suggesting that EF may operate differently within different contexts (e.g., Bechara, 2004; Hauser, 1999). Specifically, it has been suggested that one can distinguish between relatively motivationally significant aspects of EF and those which are more purely cognitive in nature (Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Zelazo, Qu, & Müller, 2005).

1.3.1 Executive functioning and motivation

A comprehensive theory of EF should include ties to other co-developing aspects of self-regulation (Carlson, 2003), including motivational systems as motivation influences the strength and direction of self-regulatory efforts (Deci & Ryan, 1987; Dweck, 1986). Specifically, Deci & Ryan (1987) argue that the regulation of intentional behavior varies along a continuum from controlled to autonomous (i.e., self-controlled), suggesting that behavior can be described as flexibly self-regulated or externally controlled. External rewards can reduce a child's capacity to regulate their behaviors by "arousing emotional responses that limit higher level thinking and flexible executive functioning” (Bronson, 2000b, p. 149). Therefore, rather than using executive capacities to analyze complex cues and problem solving strategies, a child may focus their attention on receiving a reward.

Within the literature, the relation between motivational orientations and EF has been explored theoretically (e.g., Hunt, 1965; Harter, 1999). A recently proposed framework, which attempts to internalize motivational systems in EF theory, is that of “hot” and “cool” EF (Zelazo & Müller, 2002). This framework is based upon structure-function mapping of EF abilities onto the PFC, as damage to this area of the brain yields difficulties in numerous abilities which include, but are not exhaustive of, planning, concept formation, abstract thinking, decision making, cognitive flexibility, monitoring one’s own actions, and self-control (Wise, Murray, & Gerfen, 1996). An evaluation of variable accounts of PFC functioning, each emphasizing the consequences of damage to various regions of the PFC, Zelazo and Müller (2002) make a distinction between two areas of PFC in relation to EF: relatively “cool” cognitive aspects of EF, which are related to the dorsolateral prefrontal cortex (DL-PFC) and “hot” affective aspects, which are associated with the orbitofrontal cortex (OFC; Hongwanishkul, Happaney, Lee, & Zelazo, 2005). Both of these two types of EF can be understood in terms of the degree to which they require the regulation of affect and motivation (i.e., the regulation of basic limbic system functions, Hongwanishkul et al., 2005; Zelazo & Müller, 2002). “Cool” EF is associated with more abstract, decontextualized problems, whereas “hot” EF is elicited by problems requiring affective involvement or appraisals of the affective or motivational significance of a stimulus (Zelazo & Müller, 2002). “Hot” EF, however, is invoked when individuals are invested in the problem they are solving (Zelazo, Qu, & Müller, 2005). Although it is probable that most EF tasks require a combination of both “hot” and “cool” EF, as they are both thought to be a part of a single coordinated system, this distinction manages to highlight the role emotions and motivation play in children’s EF abilities.

Traditionally, research on the development of EF has focused on measures of "cool" EF, using a number of measures including some problem solving tasks such as the Tower of London (Shallice, 1982) or the Tower of Hanoi (ToH; Simon, 1975). The Tower of Hanoi is a commonly used measure of planning which requires participants to transfer disks on pegs from an initial start state to a goal state in a limited number of moves and by abiding to specific rules (Bull, Espy, & Senn, 2004). As the difficulty of problems increases, solutions invariably involve making counter-intuitive moves: moves that are in a direction away from the goal state, and therefore necessitating more complex planning (Bull et al., 2004). Klahr (1994) has noted that these prepotent moves are challenging as the participant must plan for excess moves in order to reproduce the desired end-state configuration. Although other cognitive processes (e.g., working memory and shifting) are thought to contribute to successful performance on the ToH, it is generally described as a higher-order planning task. Extensive research using the ToH has demonstrated significant developmental shifts in performance from ages 3- to 4-years to 5- to 6-years, with adult level skill being obtained in complex move problems by adolescence (e.g., Ahonniska, Ahonen, Aro, Tolvanen, & Lyytinen., 2000; Bull et al., 2004; Welsh, Pennington, & Groisser, 1991).

Another measure of EF, which can also be considered as a "cool" EF task, is Lezak's (1982) Tinkertoy Test (TTT). In this task, participants are instructed to create something with a set of Tinker Toys and successful performance requires that the participant independently plans and produces a coherent construction (Roberts, Franzen, Furuseth, & Fuller, 1995). This construction task gives participants an opportunity to independently demonstrate their executive abilities, making it possible for them to initiate, plan, and structure a potentially complex task (Lezak, Howieson, & Loring, 2004). The TTT, thus, differs from the more widely used EF tasks as it is less structured, which in turn provides more control to the participant than the experimenter.

Although originally designed for use with clinical populations, the TTT has been most widely used as a task sensitive to executive dysfunction following traumatic brain injury. The TTT has also been used to study EF in children (e.g., Roberts et al., 1995).

Many of the current performance-based tests of EF, such as the ToH, do not assess multidimensional, relativistic decision-making, which is generally necessary in real-world situations (Goldberg & Podell, 2000). When using performance-based measures of EF, the examiner often provides structure, organization, guidance, and monitoring which may serve as source of external executive control for the child (Gioia & Isquith, 2004; Kaplan, 1988; Stuss & Benson, 1986). In these types of tasks, children's need to exercise their executive functions may be reduced and children may not need to engage in a decision making process which would involve coming up with different options among which they would need to make decisions. This may allow for children to perform appropriately on a well structured task when in fact they may have executive dysfunctions. A paradox in the assessment of executive functions is that individuals with deficits in certain EF domains may perform well on certain tests of EF but nonetheless have significant problems dealing with real-world situations (Stuss & Buckle, 1992). Accordingly, performance-based measures should be administered alongside measures which may be better at capturing a broader range of EF skills. For this reason, the TTT were used along with the ToH as measures of EF in the present study. It is anticipated that children's performance on the TTT and the ToH will be related as both are considered measures of "cool" EF and are used to assess, among other abilities, planning skills.

1.4. Language and private speech

The importance of language use in the development of higher mental functions (e.g., EF) is historically rooted in the Vygotskian tradition. The use of speech as a tool for planning and self-regulation is based on the social function of language. Initially, language serves only as a communication tool between children and others, and it is later used by children to regulate their own behaviors (Vygotsky, 1929/1994). Luria (1961) further elaborated on the regulatory function of speech, providing evidence that with age, children are able to use increasingly complex verbal commands to guide their behavior. Therefore, the regulatory functions that adults use when communicating with a child are gradually internalized by the child and then used by the child to regulate his/her behavior. These regulatory functions in turn render children “capable of voluntary, purposeful” actions (Müller, Liebermann, Frye, & Zelazo, 2007*).*

Vygotsky (1934/1986) argued that it is self-directed speech in particular that helps children to regulate their own behavior. According to Vygotsky, this was especially the case when a task becomes more difficult, as children become more likely to use private speech as an accompaniment to their behavior as task difficulty increases (Fernyhough & Fradley, 2005). Private or self-directed speech is characterized by audible self-verbalizations that are addressed either to the self or to no one person in particular (Berk, 1986; Manning, White, & Daugherty, 1994). Although the production of private speech has been reported to take place as early as 23 to 25 months (Furrow, 1984), it gradually increases with age peaks around 4- to 5-years and is abbreviated until it becomes internalized by age 8 (Diaz & Lowe, 1987; Manning et al., 1994). There has been limited support in the literature for Vygotsky’s claim that private speech goes permanently underground after this stage, as some studies have reported evidence of private speech in elementary school aged children (e.g., Berk & Garvin, 1984; Berk & Potts, 1991) and in adulthood (Duncan & Cheyne, 2002; Ferryhough & Fradley, 2005)

1.4.1. Self-regulation and private speech

Support for Vygotsky’s notion of private speech as a tool for self-regulation is found in studies demonstrating that as a task becomes more difficult, children are more likely to use private speech as an accompaniment to their behavior (e.g., Beaudichon, 1973; Duncan & Pratt, 1997; Fernyhough & Fradley, 2005). The assumption of a direct linear relation between private speech and task difficulty (e.g., Beaudichon, 1973; Duncan & Pratt, 1997) has been challenged, and it has been proposed that Vygotsky's work is suggestive of a more complex relation between these variables. In particular, it is more likely that private speech will occur when the task presented is within the 'zone of proximal development' (i.e., within the ability range; Vygotsky, 1934/1986) of the child (Behrend, Rosengren, & Perlmutter, 1989; Fernyhough & Fradley, 2005). For example, when a task is too simple, a child will not engage in private speech as it is unnecessary since all the required regulatory processes will have been internalized. On the other hand, if the task is too difficult, a child will not engage in private speech as it will be ineffective and may resort to other means of regulation (Behrend et al., 1989; Fernyhough & Fradley, 2005).

In addition to its relation to task difficulty, and in line with the Vygotskian notion of the role overt self-talk plays in self-regulation, private speech has been associated with superior task performance (e.g., Winsler, Diaz, McCarthy, Atencio, & Chabay, 1999). Private speech, however, is more often associated with concurrent task failure than task success (Frauenglass & Diaz, 1985). This implies that as a strategy that facilitates children's growing mastery over a task, private speech will be more highly correlated with future rather than concomitant success (Fernyhough & Fradley, 2005). As with the association between private speech and task difficulty, the speech-performance relation is sensitive to the level the complexity of the task the child is being presented with. When the task is too difficult, private speech is associated with failure, while when the task is within the zone of proximal development, performance is positively related to private speech (Winsler, Diaz, & Montero, 1997).

Fernyhough and Fradley (2005) investigated the relation between private speech with both task difficulty and task performance using a task that allowed for continuous task difficulty and performance measures: the Tower of London (ToL; Shallice, 1982). Unlike previous studies which have used tasks that require semantic processing (e.g., Frauenglass & Diaz, 1997), Fernyhough and Fradley chose to use the ToL because of its predominant executive component and tower tasks have been found to elicit high levels of private speech (Fernyhough, 1994). Other benefits to using a tower task include that task difficulty can be varied semantically with no variation in perceptual complexity, and it allows for performance measures to be obtained at each level of difficulty (Fernyhough and Fradley, 2005).

The results of Fernyhough and Fradley’s (2005) study supported previous findings (e.g., Behrend, Rosengren, & Perlmutter, 1989) that levels of self-regulatory private speech demonstrated a quadratic relation with task difficulty. However, Fernyhough and Fradley found that private speech was related to concurrent rather than future task performance. A plausible reason provided by the authors for this discrepancy with previous studies is the level of detail in which private speech is measured. Fernyhough and Fradley suggest that if “care is taken to consider the content” of private speech, then significant relations are likely to be found with current task performance (p. 118). Fernyhough and Fradley also suggest that the use of a task such as a tower task, which is appropriate for elicitation of private speech in preschoolers as it is pitched within children’s ability range, is more advantageous than tasks that are less likely to induce the production of private speech. Additionally, if care is taken to distinguish between the different levels of private speech (i.e., task-relevant and task-irrelevant), then speech-performance relations may become more evident than if undifferentiated measures of private speech are used.

1.4.2. Cognitive and metacognitive private speech

Given Vygotsky’s notion of the facilitative nature of private speech, children’s self-talk should serve as a reflection of their cognitive and metacognitive self-guidance

(Chiu & Alexander, 2000). The distinction between metacognitive and cognitive was not made by Vygotsky as it was not till metamemory studies of the 1970s (e.g., Flavell, Friedrichs, & Hoyt, 1970) that the term metacognition was coined (Manning, White, & Daugherty, 1994). There is general consensus within the literature that children use both cognitive and metacognitive private speech (Brown, 1987; Garner, 1988, Manning et al., 1994). Cognitive self-talk serves to focus the child's attention on a task, and involves descriptions of a task, questions regarding a task, and helps to direct the child's action in relation to a task. Metacognitive private speech reflects heightened awareness or the regulation of one's own thinking (Rohrkemper, 1986) and involves awareness of error, regulation of error emotion, and motivation as well as the awareness of solution, completion or mastery of a task (Manning et al., 1994). When a child is facing a difficult situation, metacognitive self-talk serves the function of self-correction, self-coping, and self-reinforcement (Chiu & Alexander, 2000).

Manning, White, and Daugherty (1994) used the above distinction to categorize children's task-relevant private speech and examined the qualitative differences between the different types of speech. Manning et al. (1994) investigated whether kindergarteners' private speech during independent work time reflected children's past experiences and performance in three separate studies. Each of the three studies involved categorizing children into three groups: (1) more or less autonomous based on teachers' ratings of their behaviors; (2) more or less academically advanced based on teacher ratings; and (3) more or less creative based on scores on a creativity test. Results of the study showed that children who were more autonomous, more academically advanced, or more creative displayed more task relevant cognitive and metacognitive speech than children in the other groups (Chiu & Alexander, 2000).

1.4.3. Classification of private speech

Studies examining the functional role of private speech have shown that the frequency of private speech increases with task difficulty (Berk & Winsler, 1999). However, studies examining the relation of private speech to task performance have produced mixed results (Diaz, 1992; Winsler, Diaz, & Montero, 1997). Some have reported positive (Azmitia, 1992), some negative (Frauenglass & Diaz, 1995) and some produced no correlations (Goudena, 1987) between frequency of private speech and task performance. A likely explanation for this discrepancy in the literature is the focus on children's global private speech and their global task performance, rather than specific, task-relevant aspects of private speech and task performance. Alternatively, where task-relevant private speech has been examined, significant correlations have been found by some (e.g., Goodman, 1981) but not by others (e.g., Bivens & Berk, 1990). Accordingly, it may in fact not be sufficient to simply label private speech as task-relevant or irrelevant but rather use a more comprehensive classification scheme.

Manning, White, and Daugherty (1994) devised a four level sorting process for analyzing private speech, taking into consideration both cognitive and metacognitive aspects as well as task-relevant and irrelevant aspects when creating categories and subcategories. The first, and lowest level, included task-irrelevant self-statements and questions that lacked functional significance in relation to task execution. The second level included private speech that was task-relevant but non-facilitative, the purpose of which is to delay or stop accompanying task-related behavior. Level three included task-relevant speech that was facilitative, had a cognitive focus and was aimed at planning and organizing the task at hand. The fourth, and highest level, was comprised of task-relevant speech that was facilitative and appeared to provide a metacognitive focus, allowing for verbal mediational strategies to self-correct, cope, and come to awareness of task completion. Interestingly, this level included subcategories which were considered more motivational in nature. This four level sorting process will be used in the present study in order to take into account several aspects of private speech, and with particular interest in the fourth and highest level in relation to children's motivational orientation and EF skills.

1.5. Private speech and the mediational model

Over the past 20 years, research on self-directed speech has yielded evidence that private speech can be considered as a vehicle that allows children to organize, plan, direct, and gain control over their behavior (Manning, White, & Daugherty, 1994). Specifically, private speech is thought to contribute to cognitive self-guidance, which in turn fosters the development of self-regulated learning of cognitive skills (such as EF; Schunk, 1986). Self-regulated learners are thought to be "metacognitively, motivationally, and behaviorally active participants in their own learning process" (Zimmerman, 1989, p. 4). This may be interpreted to imply that children must have certain motivational orientations as well as metacognitive capacities to be successful in the self-regulated learning of cognitive skills, such as those implied in the term executive function. Therefore, examining the role of private speech as a mediator (see Figure 1) between motivational orientations and private speech (as a metacognitive ability) may provide further insight into the processes involved in the development of EF. Each of the main paths of the model will now be discussed in turn.

1.5.1. Paths A and B: Motivational orientations and metacognitive private speech

Prior to the study by Chiu and Alexander's (2000), children's motivational orientation has rarely been examined in relation to self-speech. Chiu and Alexander posited that a potential explanation for this gap in the literature was a simple oversight of previous researchers (e.g., Jennings, Connors, & Stegman, 1988; Jennings, Connors, Stegman, Sankaranarayan, & Mendelsohn, 1985; Stipek, Gralinski, & Kopp, 1992) in examining the interaction between children's self-talk and their persistent behaviors.

Although Chiu and Alexander's did not explain their rationale for investigating such a relation, their work provided an opportunity for the further understanding of the private speech as a metacognitive ability and its relation to motivational orientations.

Chiu and Alexander calculated the proportion score of preschoolers' metacognitive private speech (using Manning, White, & Daugherty's [1994] four level classification system) in relation to their overall private speech on three tasks: a gross-motor task, a task involving hand-eye co-ordination and a puzzle task. For each of the tasks, children's mastery motivation, as measured by task persistence and desire to work independently, were significantly correlated with their metacognitive private speech and not with other types of private speech during each task. Specifically, children were more likely to complete challenging tasks or work without adult assistance if they engaged in higher proportions of metacognitive private speech. Therefore, this study provided evidence of metacognitive private speech serving a motivational function, with mastery motivation consistently related to the proportion of metacognitive self-talk. Previous research has not examined whether intrinsic or extrinsic motivation is related to the elicitation of private speech, including metacognitive private speech. In addition, it is unclear whether motivational orientations influence the production of private speech or whether private speech elicitation has an impact on motivational orientations. To further understand the nature of this relation, the present study examined the influence of motivational orientations on private speech production (i.e., Path B).

1.5.2. Path C: EF and metacognitive private speech

According to Vygotskian theory, the merging of thought and language in the form of private speech allows for the development of higher order psychological functions, such as EF. Evidence for links between private speech and executive function have been found in different types of studies, suggesting that private speech does indeed play a key role in the development of EF. For example, Frauenglass and Diaz (1985) found that self-directed speech serves a self-regulatory function for preschool children when attempting cognitive problem-solving activities such as the classification of objects into categories or ordering of pictures into a time-sequenced story. Frauenglass and Diaz also demonstrated that private speech is most likely to occur in conjunction with failure on a cognitive task. The rationale for this finding is that the production of private speech and task failure both increase with task difficulty (Frauenglass & Diaz, 1985). As mentioned previously, Fernyhough and Fradley (2005) also found a relation in preschool children between private speech and performance on a task with the predominant executive component of planning – the Tower of London task. In addition, a relation between private speech and task difficulty was found with “the highest levels of speech occurring on tasks of medium difficulty” (Fernyhough & Fradley, 2005, p.116). Unlike Chiu and Alexander’s (2000) study, not all of the above mentioned findings related metacognitive private speech with performance on EF tasks. Although all studies distinguished between task-relevant and irrelevant private speech, none made distinctions between task-relevant private speech with a cognitive versus a metacognitive focus, which was undertaken in the present study.

The influence of private speech on EF performance was investigated in this study (i.e., Path C), though others have suggested that private speech may act in tandem with EF abilities to contribute to a greater sense of self-control (e.g., Berk & Potts, 1991). As the focus of the present study was to examine the role of private speech as a mediator, only the impact of private speech on EF performance was examined.

1.5.3. Path D: Motivational orientations and EF

Clarifying the relations between private speech, motivational orientations, and EF in turn may help in elucidating the relation between motivational orientations and EF skills. Empirical evidence of an association between motivational orientations and EF in children is scarce, however, some studies, such as Chiu and Alexander’s (2000) assumed that these two constructs are related. Chiu and Alexander offered the following as an explanation for the relation between motivation and cognition:

> "…we operated under the assumption that mastery motivation and cognition are interrelated processes (Garcia & Pintrich, 1994). Children's judgment of whether to persist or seek help are likely predicated on their analysis of the task at hand and the nature of that task relative to their perceived capabilities and goals. Thus, children's cognitions may affect their mastery motivation and vice versa. For instance, children who express such self-talk as 'I almost got it!" might believe that they can accomplish the task, and children who are highly motivated may encourage themselves to try again when confronting difficulty." (Chiu & Alexander, 2000, p.139)

In the present study, the influence of intrinsic and extrinsic motivational orientations on EF performance was investigated (i.e., Path D). It is plausible, however, that EF skills also influence motivational orientations, or that a reciprocal relation exists between these two constructs. By investigating the influence of motivational orientations on EF performance, the present study helps to clarify the type of relation that exists between two constructs, which are rarely examined together.

1.6. Rationale

Given the above review, an investigation is warranted to evaluate whether the relation between motivational orientations and EF performance is mediated by private speech. The general lack of knowledge regarding the type of relation that is necessary between cognitive and motivational systems for the regulation of behavior suggests the present study would provide new and essential information regarding fundamental processes involved in cognitive development. A vital component to this line of research, which explores the role of private speech as a mediator in relating motivation and EF (see Figure 1), is the utilization of proper tools to assess each of the constructs involved.

As previously described, there are advantages to using certain measures over others when evaluating specific behavioral processes in preschool children, especially when looking at several inter-related processes. Logically, the selection of appropriate measures of EF is of utmost importance as they must facilitate the production of private speech, but must also provide an opportunity for the measurement of motivational orientations. The use of a challenging task is also crucial for several reasons: (1) a task that is not too difficult and not too easy is more likely to elicit private speech in preschoolers; (2) it allows for the measurement of persistence; and (3) a moderate level of goal-uncertainty is thought to distinguish mastery motivation from competence (McCall, 1995).

Aside from choosing appropriate EF tasks that allow for the assessment of motivational orientations and elicit private speech, the manner in which the latter two constructs are coded is critical. The present study focused on motivational orientations, which are manipulated via two reward conditions. In addition, motivation is inferred from the relation between participants' engagement in a target activity during a free-choice period and from self-reports on motivation. Private speech is coded according the categorization scheme of Manning, White, and Daugherty (1994) and Chiu and Alexander (2000), which sub-divides self-talk utterances according to task relevance and also according to whether they are cognitive or metacognitive in nature. The examination of the amount and type private speech children produce while working on tasks at hand provides further insight into the role that language plays as children are presented with more challenging situations which they may be intrinsically or extrinsically driven to succeed at.

1.7. Research design

The purpose of the present study was to assess the aforementioned mediational model in a between-subject design with a sample of 4- to 6-year-olds. Children were administered two EF tasks in succession during which their private speech elicitation was recorded. The different between-subject conditions, selected to induce various degrees of intrinsic motivational orientations during one of the EF tasks, were no reward and reward. Two types of executive functioning tasks varied in the degree to which they were structured: one task was highly structured (i.e., Tower of Hanoi), the other was less structured (i.e., TTT). It is during the Tower of Hanoi task that participants were randomly assigned to one of two reward conditions.

The outcome variables of interest were self-reports of motivation during the EF tasks, persistence at task during a free-choice period, the amount and type of private speech elicited, and performance on the EF tasks. Self-reports of motivation and persistence during free-choice periods were used together as indications of motivational orientation. The relation between free-choice behaviors and affect was of interest as these relations are thought to reflect integration in relation to the task at hand (i.e., ToH). The production as well as type of private speech produced was examined to determine differences that may occur as a result of a specific motivational orientation and how the type of private speech produced effects performance on the EF tasks. Performance on the ToH was examined to determine whether it is affected by receiving a reward. Performance on both EF tasks was examined in relation to the type of private speech produced during the tasks. Lastly, participants were also administered three subtests from the Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI-III; Wechsler, 2002): Block Design, Vocabulary, and Receptive Vocabulary. These subtests are given to serve as measures of visuocontructional ability, vocabulary, and receptive vocabulary respectively and were also meant to act as controls and to compare whether children’s abilities in the two reward groups were equal.

1.8. Research questions and hypotheses

The following research questions and hypotheses, which are centered on the mediational model, formed the basis of the current study.

1.8.1. Path A: What impact will different reward conditions have on self-reports of motivation and persistence during free-choice periods?

Based on the findings of Joussemet, Koestner, Lekes, and Houlfort (2004), rewards are anticipated to have no effect on participant's emotions during task engagement or on their behavioral persistence during the free-choice phases for the ToH. In addition, rewards are expected to be associated with a lack of congruence between children's behaviors and self-report ratings of affect. Specifically, a negative relation between children's free-choice behaviors and self-report ratings of affect will only be found for participants in the reward condition. This will be consistent with the SDT, which posits that rewards lead to an alienated form of self-regulation.

1.8.2. Path B: What impact will the different reward conditions and subsequent motivational orientations have on the amount and type of private speech produced during the ToH?

Based on previous work by Chiu and Alexander (2000), it is hypothesized that children in the no reward condition will produce the most private speech and the most metacognitive private speech. Chiu and Alexander found that more private speech, and specifically more metacognitive private speech, serves a motivational function for children when they are completing a task that is challenging but developmentally appropriate. Children in the no reward condition will have no tangible external motivation compared to children in the reward condition, and therefore may engage in private speech to motivate themselves during the ToH.

1.8.3. Path C: What impact will the amount and type of private speech have on children's performance on the TTT and ToH?

A hypothesized positive relation between the amount of private speech produced and EF performance as well as type of private speech produced and EF performance is anticipated based on previous empirical studies (e.g., Fernyhough & Fradley, 2005; Manning, White, & Daugherty, 1994). It is expected that an increase in private speech elicitation and higher production of metacognitive private speech will be correlated with scores on both the TTT and the ToH. This relationship is anticipated this will be stronger for participants in the no reward condition compared to the reward condition in the ToH.

1.8.4. Path D: What effect will the different reward conditions have on children's performance on the ToH?

Although Joussemet, Koestner, Lekes, and Houlfort (2004) found no significant differences in children's performance on a cognitive task by reward condition (i.e., reward versus no reward), other researchers have shown that children's performance on an EF task can be effected by the presence of rewards (e.g., Kerr & Zelazo, 2004). The introduction of a reward with the ToH task may cause this traditionally "cool" task to become "hot" in nature, and therefore the presence of the reward would be expected to influence children's performance. It is anticipated that children's performance on the TOH task will not differ by reward condition, however, the presence of a reward will promote an alienated form of functioning with regards to the ToH (i.e., in line with Joussemet et al.'s [2004] findings).

1.8.5. Path E: Is there a relation between children's performance on the TTT and the ToH?

It is hypothesized that significant relations will be found between children's performance on the TTT and ToH despite the differences in the degree of structure each task employs. Similarities between the two tasks, such as they are both considered "cool" EF tasks and require similar cognitive demands (e.g., planning), suggest participants' performance on the TTT and ToH will be related. In addition, both tasks have been found to be sensitive to the effects of traumatic brain injury in children (Roberts, Franzen, Furuseth, & Fuller, 1995).

2. Method

2.1. Participants

Seventy-eight preschool children between the ages of 46 and 76 months (43 boys and 35 girls, *M* = 59.33 months, *SD* = 7.59) were recruited by contacting local daycares and preschools who have previously participated in research studies with the Child Development Lab at the University of Victoria. An additional two children (mean age = 44.1) were dropped from the final sample because of uncertainties regarding normative development. Daycares and preschools were initially contacted via phone regarding their interest in having their centre participate in the study. Once the centre supervisor had given consent, permission was sought from the parents/caregivers of the children. All data on participants whose parents or teachers identify them as having special education needs, as having attention, developmental, speech-language, or cognitive difficulties was not included. The participants were divided into two age groups: Younger preschoolers (18 boys and 21 girls, *M* = 53.31, *SD* = 3.66) and older preschoolers (25 boys and 14 girls, *M* = 65.34, *SD* = 5.38). Random assignment to one of two reward conditions was blocked by gender and by age group (see Table 1).

2.2. Procedure

Participants were tested individually during a videotaped session that lasted approximately 45 minutes in a quiet room at their daycare or preschool. A female experimenter tested all participants and all sessions were videotaped. The following fixed task order was used: TTT followed by ToH. In addition, participants were administered three subtests from the Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI-III; Wechsler, 2002): Block Design, Vocabulary, and Receptive Vocabulary. For the ToH task, participants were randomly assigned to one of two reward conditions: no reward or reward.

2.3. Measures

2.3.1. EF Tasks

2.3.1.1. Tinkertoy Test (TTT; Lezak, 1982)

Fifty pieces from a Tinkertoy set were presented to participants on a clear surface (see Table 2). The participants were told, “In this game you can make whatever you want with these. You will have at least five minutes to create something. Earlier today I made something and here it is. I’m named it a zoom car.” The participant was shown the construction made by the experimenter. The experimenter then said, “Now it’s your turn to make something. I know that sometimes your teacher may ask you to be quiet while working on something. In this game you can talk as much as you like while playing.” The participant was allowed to construct an object until they indicated that the construction was complete or until five minutes had elapsed, at which point they were allowed to complete the current construction and stop. Participants who stopped handling the items were allowed to sit for 30 seconds before being asked whether they had finished. Questions about the task from the participant, such as “Should I use all the pieces?” were answered with “It’s up to you, use however many you want” by the experimenter. The experimenter’s construction was placed in front of the participant for the entire time that the participant built their own construction and the experimenter was seated near the participant. Following the completion of the task, the participant was asked “What is it?” in order to determine what the construction represented.

The construction was evaluated based on scoring criteria outlined by Bayless, Varney, and Roberts (1989). The resulting complexity score could range from -1 or less to 13, based on name, plan, function, and detail included (see Table 3). A digital photograph of each construction was taken to allow for later scoring and assessment of reliability of the scoring procedure. Three dependency scores are derived from the TTT: (1) the degree to which the participants copied the experimenter's construction (using the same shapes, colors, and pattern), with the score reflecting the number of identical pieces used in the same way; (2) the number of times children asked the experimenter for permission, opinion, or approval; and (3) the number of glances at the experimenter's picture or puzzle. Herein, these variables will be referred to as dependency copying, dependency asking, and dependency referencing respectively.

Inter-rater reliability was calculated using interclass correlations for ratings provided by two raters on 22% of the sample for children's TTT complexity score (ICC = .90, $p = .00$), the dependency copying score (ICC = 1.00, $p = .00$), the dependency asking score (ICC = .96, $p = .00$), and the dependency referencing score (ICC = 1.00, $p = .00$).

2.3.1.2. Tower of Hanoi (ToH)

Participants were presented with a model that had three equally sized large pegs. The model was identified as the participant's, and contained three different colored and sized rings stacked in a particular configuration across all three pegs. The participant was then shown a second model, which was described as the experimenter's, and had the same three differently colored rings stacked on the rightmost peg. The participant was instructed to move the three rings, only one at a time, so that their model was in the same configuration as the experimenter's. An instructional story was used to describe the goals and rules of the task (Welsh, Pennington, & Groisser, 1991): "monkeys" (the rings) of different size (daddy, mommy, and baby) jump between the "trees" (pegs), and the goal was to bring the monkeys home to sleep on their trees (i.e., achieve configuration of the experimenter's model). The participant was then informed of three rules for the task. First, only one monkey can move at a time. Second, a bigger monkey can not sit on a smaller monkey. Third, the monkeys must stay on the trees and not in the participant's hands. The ToH had the following four phases:

2.3.1.2.1. ToH Evaluation Phase

Following Bull, Espy, and Senn (2004), during the Evaluation phase each of the six types of problems were presented. The problems presented were indexed in terms of two factors: (1) increasing number of moves required for solution (i.e., two through seven moves); and (2) increasing subgoal length, reflecting the depth of search (DOS). The DOS of a problem was defined as "the number of moves needed to complete the subgoal of transferring the largest disk to its end position in a minimum sequence of steps before the complete puzzle solution is reached" (Kopecky, Chang, Klorman, Thatcher, & Borgstedt, 2005, p. 627). There were two problems with DOS = 0, one with DOS = 1, one with DOS = 2, one with DOS = 3, and one with DOS = 4 (see Figure 2). During each problem, if the participant violated one of the rules (e.g., ring placed on table, two rings moved at once, larger ring put on smaller), the experimenter gave a reminder of the violated rule. The number of moves made by the participant was recorded for each problem. If the participant moved a ring to a peg and then changed his or her mind and moved the ring back without letting go, this was counted as two moves (Bishop, Aamodt-Leaper, Creswell, McGurk, & Skuse, 2001). Trials were discontinued when a solution was reached, when 20 moves had been made, or when the participant refused to make any further moves. Testing was discontinued after two consecutive failures (i.e., refusal to make any moves, or failure to make any legal moves for a given problem).

A total-move proportion (TMP) score was calculated – an efficiency score reflecting the number of moves children required to solve the ToH problems. TMP was calculated by dividing the total possible moves which a participant could have made for all the problems presented in the phase by the number of moves the participant actually made. A lower TMP score reflects better performance as this translates to participants having the ability to complete the ToH problems in fewer moves. The minimum TMP possible is .19 as the minimum number of moves required to solve all six ToH problems is 27 and the maximum number of moves possible is 7 times 20 (i.e., 27/140 = .19). The maximum TMP score is 140/140 or 1.00.

2.3.1.2.2. Reward Phase

Following the Evaluation Phase, the two different reward conditions were manipulated during the introduction to the following phase (i.e., Reward phase) of the ToH task. Participants in the reward condition were told by the experimenter, “We are now going to go on to the next part of this game. If you play the next part of this game really well then I am going to give you the special toy that is wrapped in this box [wrapped box shown to child] when we are all done. But, if you do not play the game well then you will not get the toy. I’m going to be sitting here beside you making sure that you play the game as well as you can. So remember, if you try really hard and play this next part of this game really well, then you get to open this box and take the toy that’s inside home with you when we are all done. But, if you do not play the game well, you will not get the toy.” Participants in the no reward condition were told by the experimenter, “We are now going to play the next part of this game. I’m going to be sitting here beside you while you play the next part of this game. I hope you enjoy it. I hope that you really like it.” Participants in both conditions were reminded of the rules of the game and then presented with three ToH problems, each requiring a minimum of five moves to complete and with a DOS = 3 (see Figure 3). All three problems were presented on the table at once. The experimenter said, “Here are three different games like the ones that you just did. Try and make these jungles in the front match my jungles in the back”. The participant was reminded of the rules of the game and told to start the first five move problem. As during the Evaluation phase, if the participant violated one of the rules, the experimenter gave a reminder of the violated rule. The numbers of moves made by the participant were recorded for each problem. If the participant moved a ring to a peg and then changed his or her mind and moved the ring back without letting go, this was counted as two moves. Problems were discontinued when a solution was reached, when 20 moves had been made, or when the participant refused to make more moves. Once a participant had completed one problem, he/she was instructed to go on to the next problem. Between problems, the experimenter may have commented “Now try to make the next two jungles match”. If the participant indicated that that he/she wished to stop, the experimenter encouraged the participant to move on to the next problem. This ensured that the participant attempted each of the three ToH problems presented during this phase.

Once the participant has completed, or at least attempted, the problems in this phase, they were presented with a wrapped gift. Participants in the reward condition were told “You did such a great job in that part of the game! Here is the present that I promised you.” Participants in the no reward condition were told “You did such a great job in that part of the game! Since you did so well here’s a present for you to take home.”

As with the Evaluation phase, a total-move proportion (TMP) score was calculated. The total number of moves possible (i.e., 60 moves as there were three ToH problems) was divided by the number of moves the participant made. The minimum TMP score was 15/60 (i.e., TMP = .25) as each problem could be solved in a minimum of five moves. The maximum TMP score was 1.00

2.3.1.2.3. Free-choice Phase

Following the Reward Phase, participants were told that they had completed the previous phase. The experimenter then said, “I need to go and get something for the next game we are going to play. It may take me a few minutes to get ready. While I'm getting ready, if you want to you can try these two puzzles [experimenter showed child two new ToH problems] or you can read these books. I will just be in the other room. So it's up to you to decide what you do while I am gone: you can sit here and look at these books or you can try these extra puzzles." The books were left on the table next to the ToH problems to provide another available activity. The two problems presented varied in degree of difficulty: one easy (i.e., minimum number of moves to solution = 4 and DOS = 1) and one hard (i.e., minimum number of moves to solution = 7 and DOS = 4; see Figure 4). The experimenter moved out of the room and proceeded to prepare for the next phase. The participant was left alone by the experimenter for three minutes. After the three minutes, the experimenter returned to the table and commented on the progress that the participant had made. The experimenter also asked, "Did you like the books?" if it was evident that the participant had looked through the books.

Participants were given a score based on the number of ToH problems attempted, ranging from 0 to 2 (i.e., 0 = no problem attempted, 1 = one problem attempted, 2 = all problems attempted). A score was also given for the number of problems the participant solved correctly, ranging from 0 to 2 (i.e., 0 = no ToH problems solved correctly, 1 = one ToH problem solved correctly, 2 = both ToH problems solved correctly). A problem was considered to have been solved correctly when no rules were violated and the problem was solved in 20 moves or less. These scores were obtained by reviewing the videotape of the sessions.

2.3.1.2.4. Re-evaluation phase

The participants were told that there was one last part to the game and were presented with a final ToH problem to solve. The experimenter said, "We are now going to play the last part of the game. Here is one more puzzle for you to solve." The rules of the game were repeated prior to allowing the child to attempt the ToH problem. The problem presented was at the highest level of difficulty the participant could not solve during the Evaluation phase of the task. For example, if the first level at which the participant could not complete a ToH puzzle was a 5-move problem, they were presented with a different 5-move problem (see Figure 5). Participants were given a pass/fail score, ranging from 0 to 1 (i.e., 0 = ToH problem not solved correctly, 1 = ToH problem solved correctly). This score reflected whether the participant had successfully completed the last ToH problem within 20 moves or less.

2.3.2. Motivation

2.3.2.1. Behavioral measures of engagement

In both the TTT and the ToH, engagement time served as a behavioral measure of children's participation of each task under no external obligation.

2.3.2.1.1. Engagement during construction period of TTT

The duration of the participants' engagement in the TTT tasks during the construction period was recorded by the experimenter, which ranged from 0 to 300 seconds.

2.3.2.1.2. Engagement during Free-choice phase of ToH task

An estimate of the duration of the participants' engagement in the ToH tasks during the Free-choice phase was obtained from the videotape, with the maximum duration being 180 seconds.

2.3.2.2. Ratings of Affect

After completing the TTT and the Re-evaluation phase of the ToH, children were asked how happy they felt while doing the activity, how much they enjoyed doing the task, and how much they liked the activity. These three ratings will subsequently be referred to as the "happy", "like", and "enjoy" ratings. A visually cued scale of faces was used by participants to record their answer. The scale showed five faces ranging in expression from a big smile to a big frown, representing the range of enjoyment (e.g., the biggest smile = very happy to the biggest frown = not happy at all). Participants were asked to point to the stimulus that most closely corresponded to their feelings or beliefs. Their response was scored by using 1–5 scales, where 1 indicated the negative end of the scale (e.g., not happy at all), 2 was the second-most negative point; 3 was the scale midpoint, 4 was the second-most positive point, and 5 indicated the most positive point on the scale (e.g., very happy).

2.3.3. Private speech

Participants' speech during the construction period of the TTT and all four phases of the ToH were transcribed from the videotapes. Speech was first classified as either social or private. When the participant turned towards the experimenter, responded to conversation, or used a pronoun or name, the speech was classified as social. All other speech was classified as private.

Participants' private speech during the EF tasks were divided into utterances: segments of speech separated from other speech for three seconds or more (Diaz & Lowe, 1987, Chiu & Alexander, 2000). Each utterance was coded based on the scheme developed by Manning, White and Daughtery(1994) and used by Chiu and Alexander (2000). Within this scheme, each utterance was categorized into one of four levels: (1) off-task, (2) task-relevant and non-facilitative, (3) cognitive, and (4) metacognitive (see Table 4). The proportions of utterances for each level were calculated by dividing the frequency of participants' utterances for that level by the total frequency of utterances either during the construction phase of the TTT or across the four phases of the ToH. To assess inter-rater reliability for all codings, a naïve independent trainer second rater coded 25% of the private speech utterances. The inter-rater reliability was calculated using intraclass correlations (ICC) for the four-way distinction between the different levels of private speech. For the TTT, high intraclass correlations were found for level 1 (off-task) private speech (ICC = 1.00, p =.00), level 2 (task-relevant) private speech (ICC

= .99, $p = .00$), level 3 (cognitive) private speech (ICC = .93, $p = .00$) and level 4 (metacognitive) private speech (ICC = .92, $p = .00$). For the ToH, there was also a high level of agreement between the two raters for level 1 (ICC = 0.92, $p = .001$), level 2 (ICC = 1.00, $p = .00$), level 3 (ICC = 1.00, $p = .00$), and level 4 (ICC = 0.99, $p <=.00$) private speech.

2.3.4. Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI; Wechsler, 2002)

2.3.4.1. Block design

During this task, participants were asked to re-create a model made of blocks within a specified time limit. The experimenter presented the participant with blocks and said “Let’s play with blocks. Watch me.” The experimenter slowly assembled a model (i.e., item 1 was a two-block tower) and described the construction aloud. The experimenter placed the same types of blocks in front of the participant and said “Now you make it. Work as fast as you can and tell me when you are done. Go ahead.” The participant was allowed 30 seconds to complete his or her own construction. If the construction made by the participant was correct, then the experimenter proceeded to the next item. If the construction was incorrect, a second trial of item 1 was administered. During the second trial the experimenter modeled the correct construction with the participant’s blocks (i.e., “Watch me again”) and the participant was told “Now you make it. Work as fast as you can and tell me when you are done. Go ahead.” For each item, participants were given a score of 0 when they were unable to construct the design within the time limit and a score of 2 when they successfully constructed the design within the time limit. Items were no longer administered when participants had received three consecutive scores of 0.

2.3.4.2. Vocabulary

Participants were asked to name five items shown in a flip book and subsequently provide definitions of words read aloud by the experimenter. For the flip book items, participants were asked, “What is this?” while the experimenter showed them an image in the flip book. Participants were given a score of 0 (i.e., incorrect) or 1 (i.e., correct) for these items. For the verbal items, the experimenter said “Now I’m going to ask you what some words mean. What is a SHOE?” For each item, children were given a score of 0 to 2, with 0 represented an obviously incorrect response, 1 represented a correct answer but one that lacks content (e.g., something you tie), and 2 represented a correct response (e.g., something you wear on your feet). The subtest was discontinued after five consecutive scores of 0.

2.3.4.3. Receptive vocabulary

Participants were shown a group of four images in a flip book. The experimenter read aloud a word and asked the participant to select the picture that best illustrated what the word referred to. A correct response was given a score of 1 and an incorrect response a score of 0. The subtest was discontinued after four consecutive scores of 0.

3. Results

The results are presented in five parts. First, detailed analyses of the EF tasks are examined, including correlations between the two tasks. Second, the results of the measures of motivation are presented along with their relation to performance on the EF tasks. Third, details regarding participants’ private speech production are provided, which is followed by an examination of the relation between private speech, motivation, and performance on the EF tasks. Fourth, descriptive information about WPPSI are examined including the relations between WPPSI scores. Finally, the proposed mediational model with private speech acting as a mediator between motivation and EF is explored via a series of regression models.

3.1. EF Tasks

3.1.1. Tinkertoy Test (TTT)

Children's complexity and dependency scores on the TTT are shown in Table 5. To investigate the relations between the different TTT scores (i.e., complexity and dependency scores), correlational analyses were conducted. No significant correlations were found except between the TTT complexity score and the TTT dependency copying score, $r(78) = .28$, $p = 0.015$ (see Table 6). These results are in contrast to previous studies (e.g., Roberts, Franzen, Furuseth, & Fuller, 1995) which have found that TTT complexity and dependency scores do not correlate. In the present study, all three dependency scores significantly correlate with each other (see Table 6).

3.1.2. Tower of Hanoi performance

In the following two sections overall performance and reward condition differences were examined for each of the four phases of the ToH.

3.1.2.1. Evaluation and Reward phases

Table 7 shows the mean ToH total-move proportion (TMP) score for the Evaluation phase and the Reward phase. To examine the effect of reward condition on children's performance during the first two phases of the ToH, a MANOVA was conducted with reward condition as the between subject variable. No significant effects for the main effect of reward condition for the Evaluation phase score, $F(1, 77) = 0.02$, $p = 0.90$, or the Re-evaluation phase score, $F(1, 77) = 0.30$, $p = 0.58$, were found.

In sum, no differences were found in children's performance during the Evaluation and Reward phase scores across reward conditions.

3.1.2.2. Free-choice phase

Children's performance during the free choice phase was assessed via two categorical variables: (1) the number of problems (out of two) attempted and (2) the number of problems (out of two) solved correctly. Children's mean performance scores for this phase are found in Table 7, while Table 8 and Figure 6 show the descriptive statistics for the two aforementioned variables. The majority of children (54%) did not attempt any ToH problems during this phase, and also did not successfully solve both ToH problems (69%). To determine if there were any differences by reward condition for this phase, a MANOVA was performed to examine the effects of reward condition on the two aforementioned variables. No significant differences were found by reward condition when examining the number of problems attempted by children, F (1, 77) = .00, p = 0.99, or the number of problems solved correctly, F (1, 77) = .09, p = 0.77.

3.1.2.3. Re-evaluation phase

As participants completed ToH problems of various levels of difficulty during this phase, their performance was a pass/fail score based on whether or not they were able to solve the problem correctly. Table 7 shows that the majority of participants were able to successfully solve the ToH problem correctly. To determine the effect of reward condition on performance during this phase, a binomial logistic regression was performed (see Table 9). The regression analysis revealed that participants' pass/fail score did not vary by age reward condition, $\chi^2(1, N = 78) = 0.83$, $p = .36$.

3.1.3. Relations between performance on the TTT and the ToH

To investigate the relations between children's performance on the TTT and the ToH, correlational analyses were conducted. Specifically, correlations between ToH performance (i.e., total move proportion and pass/fail) in the Evaluation, Reward, and Re-evaluation phases with TTT performance (i.e., construction score and three dependency scores) were examined (see Table 10). Performance during the ToH Free-choice phase was not included in the analysis because not all participants attempted ToH problems during this phase. No significant relations were found between children's performance on the two EF tasks. In addition, when examined by reward condition, no significant relations were found between the two tasks.

3.2. Motivation

3.2.1. Behavioral measures of engagement

3.2.1.1. Engagement during TTT and ToH

Means and standard deviations are found in Table 11. Figures 7 and 8 show the distributions of time spent engaged in the TTT and ToH respectively. To investigate whether rewards had an impact on children's engagement time during the ToH Free-choice phase, a one-way ANOVA with reward condition as the between subject variable was performed. The ANOVA revealed no main for reward condition, F (1, 77) = 0.20, p = 0.66, indicating that the presence or absence of a reward had no impact on this behavioral measure.

3.2.1.3. Relations between the behavioral measures of engagement

To determine the relation between the two behavioral measures of engagement, correlations between the TTT construction engagement and ToH free-choice engagement times were examined by reward condition. No significant relations were found in either reward condition (ps >.20).

3.2.2. Self-reports of motivation

Means and standard deviations for children's self-reports of motivation for the TTT and ToH are found in Table 12. The distribution of children's ratings for the TTT and ToH are found in Figures 9 and 10 respectively. A MANOVA was conducted with reward as the between subject variable on the three affect ratings (i.e., happy, like, and enjoy) for the ToH. The overall model was model was not significant, F (3, 73) = 0.11, p = 0.95, and no significant effects were found. All cell means and standard deviations are reported in Table 13. Children in either reward condition did not differ on how much they liked the ToH, F (1, 77) = 0.04, p = 0.84, how happy they felt during the ToH, F (1, 77) = 0.28, p = 0.60, and how much they enjoyed doing ToH, F (1, 77) = 0.07, p = 0.79.

3.2.2.1. Relations between self-reports of motivation

To determine the relations between the three different self-reports of motivation, correlations between the different ratings were examined by task (see Table 14). In the TTT, the ratings of “like” and “enjoy” were significantly related, r(78)= .28, p = 0.013, indicating that children who said they liked the TTT were likely to report they also enjoyed playing the TTT.

Participants’ three different self-reports of motivation on the TTT showed poor internal consistency as reflected by a Cronbach's alpha coefficient of .28. For the ToH, no significant relations were found between the three ratings of affect (ps > .20). Participants’ three different self-reports of motivation on the ToH showed poor internal consistency as reflected by a Cronbach's alpha coefficient of .22.

Across the two EF tasks, significant relations were found between the two ratings of “like”, r(77)= .29, p = 0.009 and “enjoy”, r(77)= .42, p = 0.00), while the relation between the ratings of “happy” approached significance, r(77)= .21, p = 0.062. These relations indicate that children who rated these measures highly in one task were likely to do so in the other EF task. A composite variable of self-report ratings were created for each EF tasks by summing the “like” and “enjoy” ratings and is called the TTT or ToH rating of “affect” in subsequent analyses.

3.2.3. Integration of behavioral measures of engagement and self-reports of motivation

In order to examine the relations between children’s behaviors and their feelings towards the ToH correlational analyses were conducted. The correlation between behavior during the ToH Free-choice phase and each of the ToH self-report ratings were examined separately for participants in both reward conditions. Two measures of Free-choice phase behaviors are reported: (1) the proportion of time engaged in ToH puzzles, and (2) a score of which item was touched first (i.e., ToH puzzles, books, or neither). The correlations are reported in Table 15. For participants in the no-reward condition, no relation was found between behaviors and self-reports. When a reward was used, the relation between behavior and feelings about the ToH was found to be positive when reporting on how much they liked and enjoyed playing the ToH task. Specifically, the relation between the proportion of time children spent engaged in the ToH puzzles and the rating of "enjoyment" approached significance, $r(39) = .29$, $p = .072$. Also, the score of which item was touched during the Free-choice phase was significantly related to the ratings of "liking" the task, $r(39) = .33$, $p = .041$, and "enjoyment" , $r(39) = .36$, $p = .023$. The correlational analyses between the composite "affect" rating variable and the behavioral measures of engagement revealed the same pattern, with significant positive relations found only for participants in the reward condition. Now, in the reward condition, the rating of "affect" was significantly related to both the proportion of time children spent engaged in the ToH puzzles, $r(39) = .38$, $p = .017$, and the first item touched score, $r(39) = .50$, $p = .001$.

A series of Z-tests of linear contrasts between the two groups were performed. The weights used were -1 for reward and 1 for no reward (Rosnow & Rosenthal, 2002). On the relation between Free-choice phase engagement time and ratings of "enjoyment", the results were not significant, $Z = .93$, $p = .35$. For the relation between Free-choice phase engagement time and the variable "affect", the trend was not significant, $Z = 1.31$, $p = .19$. When examining the relations between the first item children touched during the Free-choice phase and self-reports of affect, no significant relationship was found between the first item touched and the ratings of "liking" the task, $Z = 1.33$, $p = .18$. However, the linear trend for first item touched and the ratings of “enjoy” were marginally significant, *Z* = 1.68, *p* = .09, and the linear trend for first item touched and the variable “affect” was significant, *Z* = 2.20, *p* = .03.

3.2.4. Motivation across EF tasks

To examine the relations between measures of motivation and performance on the two EF tasks correlational analyses were conducted. The correlations in Table 16 illustrate the relations between the measures of motivation (i.e., behavioral and self-reports) and performance on the TTT task. The significant relations found between TTT construction time and dependency asking score, *r (78)* = .24, *p* = .004, and between TTT construction time and the dependency referencing score, *r (78)* = .39, *p* = .00, indicate that children who took longer constructing asked the experimenter more questions and glanced more at the experimenter’s construction.

The correlations in Table 17 illustrate the relations between the measures of motivation and performance on the four phases of the ToH task. The significant relation found between the “like” rating and the Reward phase score, *r (77)* = -.30, *p* = .008 suggests that children who did better in the ToH Reward phase (i.e., had lower proportion scores) had higher ratings of “liking the task. A significant relation was also found between the “enjoy” rating and the Re-evaluation phase score, *r (77)* = .26, *p* = .021, indicating that children who passed the Re-evaluation phase reported higher “enjoyment” ratings towards the ToH.

Overall, different measures of motivation (i.e., behavioral vs. self-reports) correlated with EF performance in each EF task. During the TTT significant correlations were found between the behavioral measure of engagement and EF performance, while in the ToH significant relations were found between the self-report ratings of motivation and EF performance.

3.3. Private speech

3.3.1. Incidence of private speech

All speech produced by the participants during the two EF tasks was examined to determine how many participants elicited private speech, as well as the amount and level of private speech produced. Overall, eighty-three percent of children produced at least one private utterance in either EF task, and more children elicited private speech during the ToH (82.1%) than during the TTT (39.7%). Table 18 shows the mean and standard deviations for the proportion of the four levels of private speech for each of the EF tasks. The magnitude of the standard deviations in Table 18 indicates high inter-individual variability in the incidence of private speech, a pattern which has also been found in other studies (e.g., Fernyhough & Fradley, 2005; Chiu & Alexander, 2000). In both the TTT and ToH, the level of private speech produced most frequently by children was "cognitive" or level 3 private speech. A repeated measures ANOVA was carried out to examine differences in the levels of private speech produced during each EF task. For the TTT, Mauchly's test indicated that the assumption of sphericity had been violated, χ^2 (5) = 7.74, p = .17, therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .87). The results showed that there were no significant differences in the levels of private speech children produced during the TTT, F (2.6, 77.9) = 2.36, p = .087. For the ToH, Mauchly's test indicated that the assumption of sphericity held, χ^2 (5) = 86.37, p = .00. The results showed that there was a significant difference in the levels of private speech children produced during the ToH.

Post-hoc tests revealed significant differences between all levels of private speech, except between the proportions of level 2 (i.e., non-facilitative) and level 4 (i.e., metacognitive) private speech (see Table 19).

3.3.3. Private speech across reward conditions

To examine the effect of reward condition on the amount of private speech and the different levels of private speech elicited during the ToH a one-way MANOVA was performed. The analyses were performed on the amount of private speech utterances produced and proportion scores for all four levels of private speech. The experimental manipulation had no effect on either the amount or type of private speech produced during the ToH (*p*s > .18).

3.3.4. Private speech across EF tasks

Correlational analyses were conducted to examine the relations between private speech produced and performance on the two EF tasks. The correlations in Table 20 illustrate the relation between whether participants use private speech in similar ways across the two different EF tasks. Examining the correlation coefficients, two major results were found. First, a significant correlation between the amount of private speech during the TTT task and the ToH task, $r(78) = .43$, $p = 0.00$, indicates that children who elicited more private speech during the TTT expressed more private speech during the ToH. Second, the proportions of utterances in each speech category were unrelated across the two tasks. For example, children who elicited higher proportions of cognitive private speech in the TTT did not express higher proportion of cognitive private speech in the ToH.

Table 21 illustrates the relations between performance on the TTT and the type of private speech produced during the EF task. The strong significant negative correlation between the TTT construction score and proportion of level 1 private speech produced, $r(31) = -.51$, $p = 0.00$, indicates that children who received higher construction scores elicited less off-task private speech. The proportion of level 3 private speech produced during the TTT was also significantly correlated with TTT construction score, and moderately correlated with the TTT dependency copying score. That is, children who elicited a higher proportion of cognitive private speech also had higher construction scores and were less likely to copy the experimenter's construction.

The relations between ToH performance and the proportion of private speech can be found in Table 22. The only significant relation found was between performance during the Reward Phase (i.e., total-move proportion score) and the proportion of level 4 private speech produced, indicating that children who had lower (i.e., better) Reward phase scores also produced more metacognitive private speech.

3.3.4. Relation between measures of motivation and private speech

To examine the relation between the measures of motivation and private speech produced, correlational analyses were conducted. Table 23 illustrates the correlation coefficients for the measures of motivation and private speech for the TTT and the ToH.

3.3.4.1. Relation between measures of motivation and amount of private speech

Children's total private speech utterances expressed in the TTT was moderately related to amount of time they spent constructing in the TTT, $r(78) = .20$, $p = .073$, and significantly related to the ToH ratings of affect, $r(77) = .25$, $p = .027$, and the ToH proportion of level 1 private speech, $r(78) = .43$, $p = .00$. Children's total private speech utterances expressed in the ToH was not related to ToH Free-choice phase behaviors or ToH ratings of affect, rs < .13, $p > .21$, but was significantly related to the TTT ratings of affect, $r(78) = -.30$, $p = .007$.

3.3.4.2. Relation between measures of motivation and levels of private speech

By examining these correlations, two major conclusions can be drawn. First, the measures of children's motivation (i.e., behavioral and self-reports) for either EF task were not correlated to the proportion of metacognitive (i.e., level 4) private speech, rs < .14, $p > .15$, with the exception of the ToH ratings of affect and the ToH proportion of metacognitive private speech, $r(63) = .25$, $p = .05$. The only other significant relation between motivation and private speech, was the ToH Free-choice phase engagement time and the ToH proportion of non-facilitative (i.e., level 2) private speech, *r(64)* = -.31, *p* = .013. These results call into question the strength of the relation between motivation and private speech, and whether metacognitive private speech has a motivating function. Second, the proportions for the different levels of private speech were unrelated across the two tasks. That is, children who expressed higher proportions of a certain category of private speech in the TTT, did not express higher proportions in the same category of private speech in the ToH.

3.4. WPPSI

3.4.1. WPPSI scores

Correlational analyses were conducted to examine the relations between the different WPPSI subtests. The correlation coefficients in Table 24 illustrate the relations between the three subtests of the WPPSI and children's TTT and ToH performance. All subtests of the WPPSI were significantly related to each other, with the strongest relation found between the Vocabulary and Receptive Vocabulary subtests, *r* (78) = .49, *p* = .00.

3.4.2. WPPSI across Reward conditions

To determine if children in the different reward conditions had different scores on the three subtests of the WPPSI a MANOVA was conducted. The overall model was not significant, *F* (6, 71) = 0.90, *p* = 0.50, and the analyses revealed no significant main effects by reward condition for the Block Design, *F* (1, 77) = 1.66, *p* = 0.20, Vocabulary, *F* (1, 77) = 0.65, *p* = 0.42, or Receptive Vocabulary, *F* (1, 77) = 1.65, *p* = 0.20, subtests.

3.5. Mediational Model

Based on the classic work of Baron and Kenny (1986), methodologists have updated guidelines for best practices regarding mediational models (e.g., Preacher and Hayes, 2004). It has been suggested that, compared to the procedures outlined by Baron and Kenny, more rigorous methods exists for testing mediation such as the Sobel test (Sobel, 1982). This procedure “provides a more direct test of an indirect effect” (Preacher & Hayes, 2004, p.718) as it tests the significance of the mediated effect. With regards to simple mediation, the Sobel test compares the strength of the indirect effect of the independent variable on the dependent variable to the null hypothesis that the effect equals zero. To conduct the Sobel test, one needs to first carry out the causal steps outlined by Baron and Kenny (1986) in order to estimate regression coefficients for the effects of (a) the initial variable on the mediator (Path B in the present model), (b) the initial variable on the outcome (Path D in the present model), and (c) the mediator on the outcome variable controlling for the initial variable (Path C in the present model). Second, the regressions coefficients from Paths B and C are multiplied and the product (i.e., BC) is termed the “indirect effect”. Third, the standard error of the “indirect effect” is calculated. Lastly, to conduct the Sobel test, the “indirect effect” is divided by the standard error of the “indirect effect” which yields a critical ratio. This ratio is “traditionally compared to the critical value from the standard normal distribution appropriate for a given alpha level” (Preacher & Hayes, 2004, p.718).However, because the distribution of products is traditionally skewed, the distribution of the “indirect effect” is not necessarily normal and as a result, the findings from a Sobel test (i.e., which assumes that the “indirect effect” follows a normal distribution) may be called into question. Preacher and Hayes (2004) suggest the use of an alternative non-parametric approach, such as bootstrapping, which makes no assumptions about the shape and distributions of the variables. This approach involves bootstrapping the sampling distribution of the “indirect effect” and deriving a confidence interval with the empirically derived bootstrapped sampling distribution

A series of regression models, as well as tests of the “indirect effect” (i.e., the Sobel test and the bootstrapping procedure), were carried out to test the proposed mediational hypothesis, specifically the paths of the mediational model. Baron and

Kenny (1986) discussed four steps in establishing mediation: (1) showing that the initial variable (i.e., motivation) is related to the outcome variable (i.e., EF task performance), (2) showing that the initial variable (i.e., motivation) is correlated with the mediator (i.e., private speech), (3) showing that the mediator (i.e., private speech) affects the outcome (i.e., EF task performance), and (4) if steps 1 to 3 are met, the effect of motivation on ToH performance must be less in the third regression equation than in the second. Perfect mediation holds if the measures of motivation have no effect when private speech is controlled for. Steps 1 to 3 were carried out and are discussed in turn, while all results are shown in Table 25. Following this, the results of the Sobel test and the bootstrapping procedure are provided.

3.5.1. Step 1: Relating motivation to EF performance (Path D in the model)

3.5.1.1. Relating motivation to TTT performance

As the amount of time children spent constructing was significantly related to both the dependency asking and dependency referencing scores, two regression analyses were conducted to determine if either of these TTT dependency scores explained a unique amount of variance in the TTT construction time. When the dependency asking score was entered as the criterion and TTT construction time as the predictor, the TTT construction time significantly predicted dependency asking score, $\beta = .24$, $t(76) = 2.16$, $p = .034$. However, the TTT construction time only predicts a modest amount (6%) of variance in the TTT dependency asking score. When the dependency referencing score was regressed on the TTT construction time, the TTT construction time was found to be a significant predictor, $\beta = .39$, $t(76) = 3.71$, $p = .00$, accounting for 15% of the variance in the dependency referencing score. As none of the TTT self-reports of motivation, including the Affect score (i.e., the sum of the “liking” and “enjoyment” ratings), significantly correlated with TTT performance scores (see Table 16), regression analyses with these variables were not carried out.

3.5.1.2. Relating motivation to ToH performance

In prior analyses (see Table 17), children's engagement time during the ToH Free-choice period did not significantly correlate with any ToH performance scores and was therefore not subjected to regression analyses. As the ToH ratings of "like", "enjoy" and the "affect" composite did correlate significantly with ToH performance score from the various phases of the ToH task, regression analyses were carried out with the self-report ratings as predictors. When the ToH Reward phase proportion score was regressed on the ToH "like" ratings, the rating of "like" was a significant predictor, $\beta = -.30$, $t(76) = -2.73$, $p = .01$, accounting for 9% of the variance in the ToH Reward phase score. Next, the ToH Reward phase score was regressed on the ToH "affect" rating (i.e., sum of the "like" and "enjoy" ratings), and the rating of "affect" was also found to be a significant predictor, $\beta = -.33$, $t(76) = -2.99$, $p = .004$, and accounted for a larger 11% of variance in the Reward phase score. Lastly, the ToH Re-evaluation phase score was regressed on the ToH "Enjoy" rating, and the "enjoy" rating was a significant predictor of ToH Re-evaluation phase performance, $\beta = .26$, $t(76) = 2.36$, $p = .02$, accounting for 7% of variance in the Re-evaluation phase scores.

Based on the above significant results the regression of EF performance scores on measures of motivation, it can be concluded that motivation is correlated with EF performance, and there is an effect between motivation and EF that may be mediated.

3.5.2. Step 2: Relating motivation to private speech (Path B in the model)

In the TTT, no measure of motivation was significantly correlated with either the amount or type of private speech elicited during the TTT (see Table 23). For the ToH, as Free-choice phase engagement time and the composite "affect" rating were significantly correlated with two different types of private speech elicited during the ToH, separate regression analyses were performed with engagement time and self-report ratings as predictors. When the proportion of level 2 private speech produced was regressed on

ToH Free-choice engagement time, Free-choice engagement time significantly predicted the proportion of level 2 private speech elicited, β = -.31, *t*(76) = -2.55, *p* = .013, explaining 10% of the variance in the proportion of non-facilitative private speech produced. Next, when the proportion of level 4 private speech produced was regressed on to the "affect" rating, the self-report rating was found to be a significant predictor of the amount of level 4 private speech produced, β = .25, *t*(76) = 2.00, *p* = .05, and accounted for 6% of the variance in the amount of metacognitive private speech elicited.

These regression analyses demonstrate that motivation is correlated with private speech, and show that during the ToH task motivation influenced the type of private speech children produced.

3.5.3. Step 3: Relating private speech to EF performance (Path C in the model)

As private speech may correlate with children's EF performance simply because both variables are caused by motivation, it is not sufficient to show that private speech and EF correlate. Motivation must be controlled in establishing the effect of private speech on EF performance. Consequently, EF performance was used as the criterion variable in the regression equation, with private speech and motivation as predictors. Specifically, performance during the ToH Reward Phase was regressed on the amount of level 4 private speech produced during the ToH and the ToH "affect" rating. While the overall model was significant, R^2 = .18, *F*(2, 62) = 6.52, *p* = .003, with the two predictors accounting for 18% of the variance in performance during the ToH Reward phase, both predictors did not demonstrate significant effects on ToH Reward phase performance. The ToH "affect" rating was a significant predictor (β = -.34, *t*(60) = -2.84, *p* = .006) while the proportion of level 4 private speech was not (β = -.18, *t*(60) = -1.45, *p* = .15). These results reveal that private speech did not affect performance on the ToH task, suggesting that the mediator in the proposed model did not affect the outcome variable.

As this third step in determining mediation was not met, the data are inconsistent with the hypothesis that private speech mediates the relation between motivation and EF.

3.5.4. Tests of the indirect effect

The Sobel test directly addresses the primary question of interest — whether or not the total effect of the independent variable (i.e., self-reports of affect) on the outcome variable (i.e., performance on the ToH) is significantly reduced upon the addition of a mediator (i.e., private speech) to the model. In the present study, the Sobel test supports the Baron and Kenny (1986) strategy and suggests no mediation occurred (z = 1.09, p = .28).

The bootstrapped estimate of the indirect effect is similar to the point estimate computed from the conventional regression analysis of the raw data. The true indirect effect is estimated to lie between -.1057 and .0129 with 95% confidence. As zero is in the 95% confidence interval, we can conclude that the indirect effect is not significantly different from zero at p =.05 (two tailed).

Thus, both the Sobel test and the bootstrapping procedure confirmed that the effect of children's self-reports of affect on performance in the ToH is not mediated by the proportion of metacognitive private speech they produce.

4. Discussion

The primary aim of the present study was to investigate the role of private speech as a mediator between motivational orientations and EF performance in preschoolers. Preschool children were administered two EF tasks and randomly placed in one of two reward conditions, selected to induce differential motivational orientations. The private speech that children elicited during the two EF tasks was examined and classified into four distinct categories. Although relations were found between measures of motivation, private speech, and EF performance, private speech did not act as a generative mechanism through which motivation influenced children's performance on the EF tasks. This study represents the first attempt to explore such a model in this age group and results provide preliminary information about how private speech, motivation, and EF are related in regard to children's goal directed behaviors.

4.1. Executive functioning tasks

4.1.1. Tinkertoy test

The utilization of the TTT as a measure of EF in preschoolers in the present study was unique as the TTT is typically used with clinical samples and is rarely used in conjunction with other performance-based tests of EF. Previous research using the TTT as an assessment tool in the study of EF in elementary school age children failed to find developmental trends in TTT performance (e.g., Roberts, Franzen, Furusethm, & Fuller, 1995). The results presented herein replicate Roberts et al.'s findings, suggesting that the manifestation of developmental trends in EF may be task-specific during the preschool years. The TTT differs greatly from other performance-based tests typically used to assess the development of EF as it places a degree of control in the hands of the participant. This is in contrast to most other performance-based tests, such as the ToH, where the task itself is highly structured and the specific goal the participant must achieve is clearly presented. For example, in a ToH problem, children are presented with a start state and shown a goal state. Children must strive to achieve the goal state by moving the rings around the apparatus while keeping in mind the rules of the game. In the TTT, the instructions participants receive included an open-ended goal state when they were told they can construct what ever they like with 50 Tinkertoy pieces. Additionally, no constraints are conveyed to the participant during the TTT. Thus, the unstructured nature of the TTT and the placement of "executive responsibility" (Lezak, 1982, p. 291) in the hands of the participant may prevent the TTT from being a thorough measure in age-related changes in EF compared to other performance based tests of

EF. However, these characteristics of the task may aid in making the TTT sensitive to other cognitive differences (e.g., ability to formulate and achieve a goal) within the preschool years. In addition, it may be more difficult to detect developmental differences in an unstructured EF task such as the TTT, as a specific component of EF is not being targeted. Consequently, the TTT may be too broad of a measure to be sensitive to age related changes during the preschool period.

Overall, the TTT may be limited in its sensitivity in capturing early stages of EF development in a typical population as it was designed for use with a clinical population. However, the TTT may serve as an additional and innovative psychometric method for sampling representative components (i.e., planning and organization) of EF that can not be captured by more commonplace and highly structured measures of EF (Roberts, Franzen, Furuseth, & Fuller, 1995).

4.1.2. Tower of Hanoi

The experimental manipulation of motivation (i.e., reward) did not have an impact on ToH performance during the Reward, Free-choice or Re-evaluation phases. This finding is similar to that of Joussemet Koestner, Lekes, and Houlfort (2004), where elementary school age children’s performance during a free-choice period was not affected whether they were in the reward or no-reward condition. That is, Joussemet et al. found that children’s performance on the previously introduced activity (e.g., Continuous Performance Test) did not differ (*p*s > .20) depending on whether or not they were told prior to the free-choice period that they would be receiving a reward.

4.1.3. Relation between the TTT and ToH

Similarities between the TTT and the ToH, such as they are both considered “cool” EF tasks and require similar cognitive demands (e.g., planning), informed the original hypothesis that participants’ performance on the two EF tasks would be related. Moreover, both tasks have been found to be sensitive to the effects of traumatic brain injury in children (Roberts, Franzen, Furuseth, & Fuller, 1995). Significant relations between the two EF tasks were not present.

The aforementioned results suggest that children's performance on the TTT relates only to their performance in one phase of the ToH, namely the Evaluation phase of the ToH task, which is the phase that is identical to the manner in which the ToH is typically administered. The lack of relations between performance on the TTT and on subsequent phases of the ToH may be as a result of differences in the method of presentation of ToH problems. During the ToH Evaluation phase, ToH problems are presented one at a time, allowing children to focus and attempt each problem individually. During the ToH Reward and Free-choice phases, several ToH problems are presented at the same time, which may have required children to keep several goals in mind.

The present study is the first to evaluate typically developing preschoolers' performance on the TTT in relation to their performance on a commonly used test of planning and organization in children. The absence of strong, significant correlation between the TTT and the ToH suggests that the two tasks are sensitive to different planning abilities in preschool children and could be used in conjunction as part of a battery of tests.

4.2. Motivation

4.2.1. Behavioral measures of engagement and self-reports of motivation

Overall, no effects of rewards were found on participant's feelings towards the tasks or on their behavioral persistence during the Free-choice phase. It can be concluded here, as has been by others (e.g., Joussemet et al., 2004), that rewards have no impact on the individual measures of cognition, affect, or behavior.

4.2.2. Relations between behavioral measures of engagement and self-reports of motivation

The majority of previous studies have suggested that there is no clear benefit to or detriment of rewards being used. These studies, however, were limited in that they relied solely on self-report or free-choice measures of motivation (Joussemet, Koestner, Lekes, & Houlfort, 2004). Examining the congruence between children's behaviors and their feelings towards a task provides a better assessment of the impact of controlling rewards on the level of integration in self-regulation than looking at behaviors and feelings separately. The correlations between the proportions of free-choice behaviors in the present study revealed that when a reward was used, the relation between behavior and feelings about the task was positive. Meaning, receiving a reward was more beneficial than not receiving one and the use of rewards resulted in children having more positive feelings about the ToH. Importantly, these results suggest that the reward effects were positive and associated with a more integrated form of self-regulation.

This pattern of correlational results between free-choice behavior and feelings about the task presented are inconsistent with those obtained in a previous study (e.g., Joussemet, Koestner, Lekes, & Houlfort, 2004) and with self-determination theory (SDT). In previous studies, rewards were found to have a negative effect on the relation between behavior and feelings causing an alienated form of self-regulation. According to SDT, the natural tendency of individuals to internalize extrinsic values and regulations within the self can be challenged by social contexts such as rewards. Indeed, Joussemet et al. (2004) have shown that rewards were one factor that hindered integrated self-regulation and therefore have a "pernicious" effect on self-regulation.

This raises the question as to why the results of the present study differ from other studies which have examined the effects of rewards on internalization? The answer may be related to the type of instructions given to children during the different phases of the ToH. Joussemet, Koestner, Lekes, and Houlfort (2004) found significant negative correlations between feelings and behavior when instructions were presented in a controlling and more directive way as opposed to an autonomy-supportive manner. Accordingly, autonomy support was found to have various positive effects on children's ability to "self-regulate in an integrated manner" (Joussemet et al., 2004, p.159). Autonomy-supportive instructions involve the communication of choice, while more directive instructions such as "should" and "must" were included as part of instructions that are controlling. Supporting a child's autonomy also involves encouraging self-initiation and personal responsibility, being clear and consistent, and setting limits in an understandable way (Joussemet et al., 2004; Deci & Flaste, 1995).

In the present study, both controlling and autonomy-supportive instructions were given in different phases of the ToH. For example, the ToH was initially introduced in a controlling way (i.e., during the Evaluation phase), whereas the manner in which the reward was introduced was done in such a way that it may be characterized as more autonomy-supportive. When introducing the Evaluation phase, children are told what rules they need to follow and then asked to make their "jungle" match the experimenter's "jungle". During the introduction to the ToH Reward phase, children were not merely told that they were going to get a gift if they continued to solve ToH puzzles. Rather, participants were encouraged to "… try really hard and play this next part of this game really well, then you get to open this box and take the toy that's inside home with you when we are all done". Consequently, the instructions did not simply direct children to attempt the ToH problems, but implied that it was the child's responsibility to chose whether or not they would get the reward, for receiving the reward depended on the effort that they demonstrated during this phase of the game. This slight change in the manner in which the instructions were provided during the Reward phase may serve as an explanation for the more integrated form of self-regulation found in the reward condition.

Joussemet, Koestner, Lekes, and Houlfort (2004) reported that the joint effect of autonomy support plus reward (i.e., positive correlations) found in their study was difficult to interpret as it appeared that combining autonomy-supportive instructions and rewards lead to a low level of congruence in self-regulation. In the present study, perhaps it was the combination of controlling and autonomy-supportive instructions that enhanced the joint effect of instructions and rewards that lead to the positive outcome of integrated self-regulation. Notably the joint effect of instructions and rewards was carried out in a manner that has not been previously investigated. Determining the factors that support this integration is important as clinical researchers have suggested that it represents a hallmark of healthy and adaptive self-regulation (Joussemet et al., 2004; Gruen, 1988).

As previous studies have primarily examined the effects of rewards on internalization in school aged children (e.g., Swann & Pittman, 1977), the present results provide an (initial) indication that differences are found in younger children's actions. Specifically, the joint effect of instruction and rewards influences younger children's behavior and feelings in a different manner compared to their older counterparts (i.e., school-aged children). For example, it has been shown that school-aged children's persistence at an interesting task can remain high when a tangible performance-contingent reward is paired with positive verbal reinforcement (Swann & Pittman, 1977). Aside from differences in instructional style, the present study involved somewhat younger children than those reported on by Joussemet, Koestner, Lekes, and Houlfort (2004; i.e., first through fifth graders) and others. Therefore, further clarification as to how age may factor into children's integrated self-regulation is needed, as is determining when over the course of development age related changes occur.

4.3. Private speech

The fact that the majority of participants in the study did elicit some form of private speech across the two EF tasks confirms Vygotsky's notion that private speech represents a common phenomenon in development (Fernyhough & Fradley, 2005, Winsler, de Leon, Wallace, Carlton, & Willson-Quale, 2003). Interestingly, more children produced private speech during the ToH than during the TTT, and children who did elicit private speech in the TTT were likely to do so in the ToH. The lack of private speech during the TTT may be attributed to two factors. First, the TTT was the initial task administered to children during the testing session and the first controlled interaction that took place between the experimenter and each child. Despite evidence that private speech is stimulated by the presence of others (Goudena, 1987), uncertainty about the testing session or about the experimenter herself may have caused children to feel uncomfortable eliciting private speech. However, by the time the ToH was administered, children may have felt more comfortable with the situation and therefore were more prone to elicit private speech. Second, the lack of structure and the absence of a clear goal state in the TTT are contextual factors that may have lead children to produce less private speech. Compared to the ToH, the TTT involves children working towards a goal that they have set for themselves (i.e., deciding what to build with the Tinkertoys). Therefore, children may not have needed to organize, plan, and gain control over their behavior via private speech during the TTT as much as they did during the ToH task. Perhaps this is because when children are working towards a goal which they have set themselves, they do not require as much private speech to regulate their behaviors as compared to when they are trying to achieve a goal set by someone other than themselves.

For both tasks, children produced more cognitive private speech compared to the other levels. That is, the kind of private speech elicited by children indicated that they were engaged in focusing, describing, questioning, and directing themselves with regards to the task at hand (i.e., TTT or ToH). As both the TTT and ToH are tasks are designed to assess cognitive processes, specifically planning and organization, it is plausible to expect that if children do elicit private speech they would engage in private speech that reflects mental attention, planning and organization.

4.4. The paths of the mediational model

4.4.1. Motivation and EF (Path D)

Diverse results can be found in the literature regarding the relation between motivation and EF. Some researchers have demonstrated that preschoolers are sensitive to rewards and motivated to receive them (e.g., Kerr & Zelazo, 2004), while others have shown rewards have no direct effect children's cognitive performance (Joussemet, Koestner, Lekes, & Houlfort, 2004). The current study provides new evidence of the effect of rewards on cognitive performance. Although rewards were found to have no effects on children's performance on the ToH in the present study, the presence of rewards did promote integrated functioning with respect to the ToH. In addition, no differences were found in free-choice engagement time or self-report ratings of affect by reward condition. When examining the relations between the self-report measures of motivation and EF performance, it was found that children who had higher ratings of positive affect towards the ToH also performed better in the Reward and Re-evaluation phases of the ToH.

The results do support the common practice of using rewards to promote children's interest and integration of task. However, the interpretation of the findings also supports the use of an autonomy-supportive approach with children (see above). Goals, guidelines, and limit setting are all important factors that should be maintained as without such structure children would most likely be unable to internalize cultural values (Grolnick, 2003). These structures, however, should be provided in a context that supports autonomy. An example of such an approach is the involvement of a parent or teacher using a reward and having them promote the value of doing the task at hand.

When testing the proposed mediational model, it was found that the behavioral measure of engagement in the TTT significantly predicted various measures of TTT performance, while self-report measures of affect served as significant predictors of performance during certain phases of the ToH task. These results suggest that measures of motivation are indeed related to children's performance on an EF task, but that different measures of motivation are related to differentially structured EF tasks. It appears that behavioral measures of engagement are predictive of children's performance on unstructured tasks, while self-report measures of positive affect are predictive of performance on the more conventional structured EF tasks.

Prior to the current study, little was known as to how motivational orientations related to EF within development. The majority of studies that examined how motivation influences EF have done so either within the context of examining children's performance on tasks which require "hot" and "cool" forms of EF or by examining the effects of rewards on children's problem solving abilities. By using rewards as a manipulation of motivation in conjunction with "cool" EF tasks, this study provided a new and unique perspective on how motivation and cognition are related in development. The results presented here lay the groundwork for further exploration as to how adaptive motivational orientations can influence children's performance on other tasks that assess different components of EF and "hot" versus "cool" measures of EF.

4.4.2. Relations between motivation and private speech (Path B)

Generally, researchers who study private speech use the frequency of utterances per minute as an indicator of children's development or learning. It is possible, however, that children's total utterances for a task may be influenced by (1) their motivation to complete the task; (2) time spent on the task; or (3) their individual tendency to elicit private speech (Chiu & Alexander, 2000). In order to examine the motivational effect on children's private speech, the influences of time and individual tendency were controlled for by examining the proportion of private speech for each speech category. Although the effect of reward condition on the amount or type of private speech produced was null, significant correlations were found between behavioral measures of engagement and self-report measures of motivation and private speech during the ToH.

The lack of effect of reward condition on the amount or type of private speech elicited in the study was unexpected as it was anticipated that more metacognitive private speech would be produced by in children in the no reward condition. Previous empirical findings (e.g., Chiu & Alexander, 2000) have shown that more private speech, and specifically more metacognitive private speech, serves as a motivational function for children when they are completing a task. Children in the no reward condition had no tangible external motivation compared to children in the reward condition, and therefore it was thought that they may engage in metacognitive private speech to motivate themselves during the ToH. These results suggest either that children in the no reward condition did not require metacognitive speech as a source of motivation or that children in the reward condition also required metacognitive speech to motivate themselves to complete the ToH task.

The significant positive relation between the ToH rating of "affect" and the proportion of metacognitive private speech produced during the ToH supports the notion of metacognitive private speech serving a motivational function. However, the absence of significant relations between any other measure of motivation (i.e., engagement time and other ratings of affect) and metacognitive private speech in either EF tasks calls into question the motivational role metacognitive speech may play. This result differs from the findings of other researchers who have reported consistent relations between measures of motivation and elicitation of metacognitive private speech. For example, Chiu and Alexander's (2000) found that children's mastery motivation, gauged by their persistence and desire to complete a task, was constantly mirrored in the proportion of metacognitive private speech elicited across three different tasks (e.g., gross motor versus puzzle tasks). The inconsistency between the current study's findings and those of Chiu and Alexander may be due to the different types of tasks employed, as well as the different methods used to measure motivational orientations.

The regression analysis showed that ratings of positive affect were predictive of metacognitive private speech during the ToH. However, the findings in this study cannot clarify when positive feelings a task may lead young children to express metacognitive private speech as no relationship was found between self-reports of affect and metacognitive private speech in the TTT. Overall, the findings confirm a relation between motivational orientations and metacognitive private speech, but they do not help to clarify the direction of the effect. Although there are indications of aspect of a child's motivational orientations influencing the amount of metacognitive private speech they produced, this relation needs to be addressed by future studies to determine why this may not occur for certain EF tasks and if the two processes may operate in a reciprocal manner.

4.4.3. Relations between private speech and EF (Path C)

Private speech has been previously studied in relation to children's performance on tasks with high executive demand characteristics such as the Tower of Hanoi (e.g., Fernyhough & Fadley, 2005; Kopecky, Chang, Klorman, Thatcher, & Borgstedt, 2005). There are two reasons as to why the relations examined in the present study differ from those who have previously used the ToH. First, the study did not concern itself with looking at how private speech was related to task difficulty, for it only investigated the how private speech may affect task performance. Second, categorizing private speech into four distinct categories, which took into account its task relevance and its cognitive nature, is not typical of research on private speech. The results of this study indicate that private speech does play a role in the performance of EF, but do not provide conclusive evidence as to the role that metacognitive private speech may play in this context.

The finding that proportions of utterances for each category of private speech were not related across the two EF tasks is consistent with the findings of Chiu and Alexander (2000) who used the same classification system for private speech. Chiu and Alexander believe that these results support the idea that revealing patterns exist in the type of private speech children produce and that the qualitative differences reflect children's task specific motivation (Chiu & Alexander, 2000, p.148)

It is when looking at the within task relation between private speech production and EF performance that evidence was found for a link between private speech and EF. Children who had a higher and, therefore, more advanced TTT construction score used less off-task private speech during the TTT. This indicates that children who possessed adequate cognitive competencies to attend to the task at hand (i.e., the TTT) and were able to screen out any distracters (Manning, White, & Daughtery, 1994; Corno, 1987). Children who performed better in the Reward phase of the ToH exhibited significantly more metacognitive private speech. This indicates that children who were better at solving the ToH problems presented during the Reward phase engaged in more self-correction, were better able to cope with frustration, and realized when they had arrived at a solution. This finding is supported by previous work, which has suggested that metacognition is more likely to occur when the task is somewhere between familiar and unfamiliar (Flavell, 1987). Therefore, during the Reward phase, children were most likely capable task-wise as they had gained some experience with ToH problems during the Evaluation phase, but also optimally challenged and motivated as they were presented with three new ToH problems.

When testing the mediational model, metacognitive private speech did not significantly predict children's performance on the ToH when controlling for motivation. Interestingly, metacognitive speech does significantly predict performance in the Reward phase of the ToH when motivation is not controlled for, with metacognitive private speech accounting for 8% of the variance in Reward phase score. Accordingly, the present study established that metacognitive private speech can act as a predictor of children's performance on an EF task. This suggests that private speech does indeed play a role in relating motivation with EF and further empirical testing is required to determine exactly how private speech may contribute to these processes within development.

4.4.4. Conclusions regarding the mediational model

The main hypothesis for the present study was that private speech acts as a mediator in relating motivational orientations and EF within development. Regression analyses and the tests of the indirect effect provided support for the initial variable (i.e., motivation as measured by behavior and self-reports) serving as a significant predictor for both the outcome variable (i.e., EF performance) and the mediator (i.e., private speech production), and the mediator significantly predicting the outcome variable. However, the mediator did not significantly predict the outcome variable when controlling for the initial variable. As some researchers (Kenny, Kashy, & Bolder, 1998) have questioned whether all four steps outlined by Baron and Kenny (1986) need to be met for mediation to occur, it remained uncertain whether or not private speech could be discounted as a mediator. Subsequently, two tests of the indirect effect, the Sobel test and Bootstrapping, were carried out. The Sobel test is thought to be more accurate than the Baron and Kenny method, but it lacks statistical power. Bootstrapping has become the preferred method of testing for mediation as it is the only test which does not violate normality and is recommended for smaller sample sizes (Dearing & Hamilton, 2006).

Based on the non-significant results of both tests of the indirect effect, it is clear that complete mediation did not occur in the present model.

4.5. Future Research

Overall, the results presented here confirm that it is worthwhile to focus on and further investigate children's private speech and its relation to adaptive motivational orientations and performance on tasks assessing EF. In addition, particular forms of private speech may provide key information to further understand how children face challenges. This paper suggests that future research continue to take care to distinguish sub-types of private speech and to use cognitive tasks which are appropriate for the elicitation of private speech.

With regards to task selection, a logical extension of the present study would be an investigation which uses tasks designed to measure different processes involved in EF such as inhibition, working memory and attentional flexibility. An example of such a task is the Gift Delay task, a task in which children must refrain from opening a wrapped gift that is presented to them and wait until an experimenter returns before opening it. Delay tasks have been used to examine how children's behavior changes as they move from the egocentric world of their family to the social world beyond the family, where there is an increased demand for the self-regulation of behavior (e.g., Vaughn, Kopp, Krakow, Johnson, & Schwartz, 1986). Although delay tasks have never been shown to elicit private speech in children, encouragement to do so during the task, as done in the present study with both EF tasks, would likely cause children to talk to themselves while waiting for the experimenter. An additional benefit to using a task such as the Gift Delay is that is not limited in its ecological validity as it mimics a situation which children may encounter in their everyday lives.

With regards to motivation, further empirical work is needed to determine why children in the reward condition have an integrated form of self-regulation as opposed to the alienated form of self-regulation predicted by previous studies. Based on the interpretation of the unexpected finding of children's integrated self-regulation in the reward condition, the next step would be to determine if the type of instructions used in the present study did indeed influence children's behavior by contrasting the impact of autonomy-supportive instructions with more controlling ones. In addition, it would be important to use these contrasting instruction styles with different types of EF tasks to determine if the use of rewards in all EF tasks promotes an integrated self-regulation process.

An objective for future studies would be to further investigate how and what type of private speech is involved in how children's motivational orientations influence their performance on EF tasks. One option would be to investigate a moderated-mediational model where private speech would affect the direction and strength of the relation between the development of motivational orientations and EF. A moderated-mediational model would imply that self-directed speech serves to promote the influence adaptive motivational orientations and EF have on each other within development. For example, private speech may act in concert with adaptive motivational orientations to further enhance executive function development in children, which in turn may then promote continued adaptive motivational patterns. Thus, testing the moderating effects of private speech would contribute to an enriched understanding of the processes involved in motivational orientations and EF.

An additional suggestion for future research is that it employ a longitudinal methodology. Utilizing such an approach has proven to be productive in confirming Vygotsky's claim that private speech follows a developmental path. Further, studies have found that "private speech follows a developmental sequence beginning with task-irrelevant external private speech, then progressing to task-relevant external private speech, and finally to fully internalized self-guiding speech" (Corkum, Humphries, Mullane, & Theriaul, 2008, p. 99). Similarly, valuable contributions may emerge from longitudinal studies examining private speech in relation to motivational orientations and EF abilities within development. A longitudinal study could examine several issues raised by the results reported here such as how age factors into (1) integrated self-regulation, (2) the production of different levels of private speech, and (3) the relation between integrated self-regulation and performance on “hot” and “cool” measures of EF.

Although the findings of the current study represent important first steps from a theoretical perspective, several limitations should be also addressed by future research. First, the sample used in the present study imposed restrictions. The study consisted of a relatively small sample size with slightly more male participants in both the reward and no reward conditions. However, the effect sizes (as measured by partial eta squared) fell in the small to medium range, which indicates that the analyses had enough power to indicate differences between groups. Second, the results presented did not fully address the direction of the effect between motivational orientations and performance on EF tasks. Although the results of the analyses examining the mediational model indicated that measures of motivational orientations are predictive of performance on an EF task, it is unknown whether these two dimensions operate in a reciprocal manner. Determining the nature of this relation requires further empirical testing. Third, the manner in which private speech was categorized (i.e., into four distinct categories) may have been restrictive, preventing further relations between private speech and the other constructs from being revealed. By classifying children’s private speech utterances into categories which serve as a better reflection of their motivational orientations, or by examining children’s private speech in relation to their accompanying behaviors may have provided richer data with respect to children’s self-talk. The objectives of future studies examining private speech should including an exploration into different methods of categorizing private speech, which may provide more meaningful insight into the role private speech may play within cognitive development. Fourth, the measures of motivational orientations used in the present study may not have been adequate representations of children's orientations towards the tasks at hand. For example, there was very little variability in children's self-report ratings of affect during the ToH with most children reporting positive feelings towards the task (see Figure 10). In addition, engagement time during the Free-choice phase of the ToH may not have been an accurate reflection of children's motivation as children could not engage for the full free-choice period in the ToH problems if they had solved both problems prior to the Free-choice phase being complete (i.e., prior to the three minutes elapsing). Related is a fifth limitation, which is the use of single item scales for measuring children's self-reports of affect. Though this format is the most practical when working with young children (Joussemet, Koestner, Lekes, & Houlfort, 2004), it may be better to include multiple-item scales to measure children's affect towards the tasks administered in future studies. Sixth, as the current study used experimental tasks, it was limited in its ecological validity. Future studies could incorporate more real-life tasks, such as the gift delay task, and include parent, teacher or caregiver reports of children's everyday, real world functioning. These modifications would add a high level of ecological validity in order to further understand behavioral manifestations of executive function.

5. Conclusion

The analysis of the relation between motivation, private speech and EF, represents an important initial step in elucidating the relations between motivational orientations and EF. Empirically examining the mediating effect of private speech fills a gap in the literature with regards to understanding the processes involved in motivational orientations and EF in development. It provides new and important information as to how motivational orientations and EF may be related, and extends previous literature examining the relation between motivational orientations and private speech as well as EF and private speech. What remains to be elucidated is the exact nature of the differential associations between these three processes and as such knowledge would provide further insight into the development of self-regulation.

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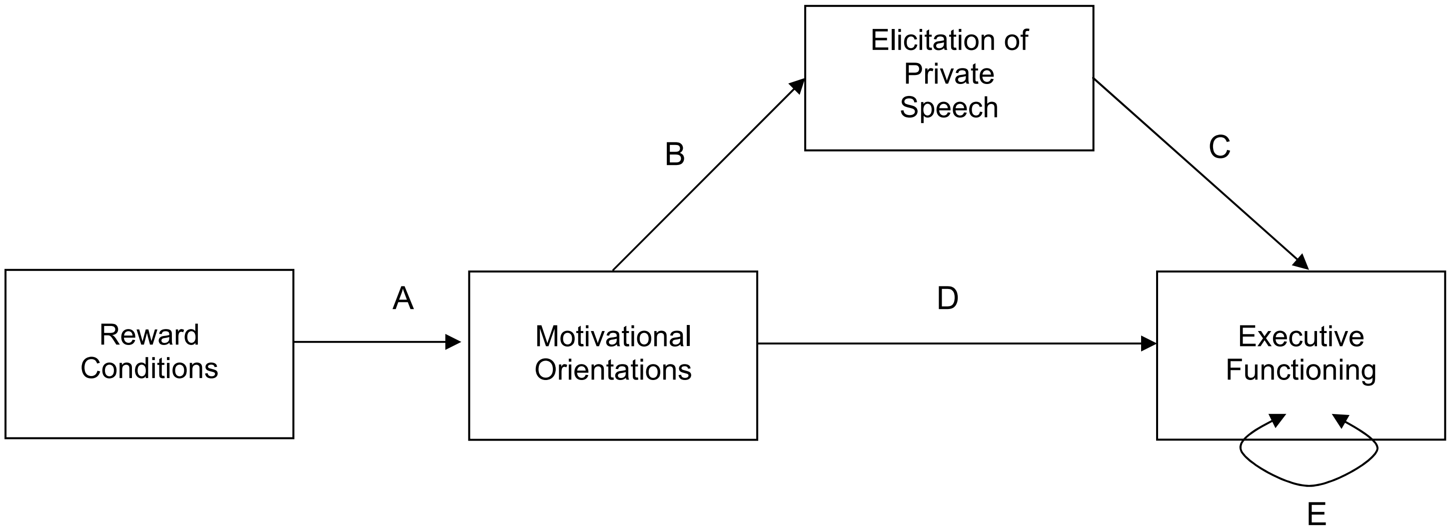


Figure 1. Proposed Mediational Model.

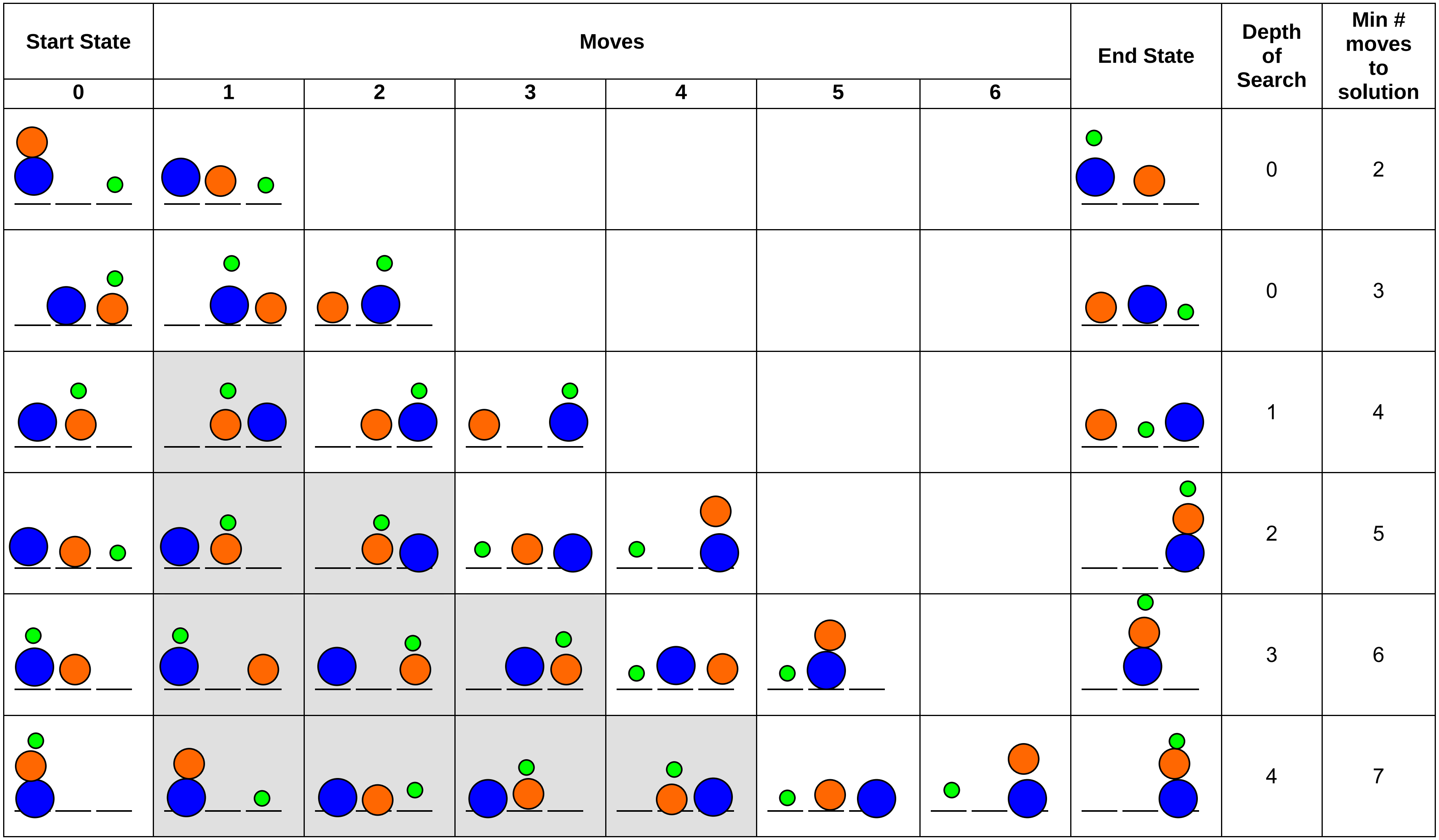


Figure 2. Diagram of Problems Presented in the Evaluation Phase. The problems vary in terms of Depth of Search (DOS) and minimum number of moves to solution (MTS). The MTS for each type of problem is outlined in the figure (moves 1-6). The shaded ring arrangements correspond to the moves in each problem that define the DOS.

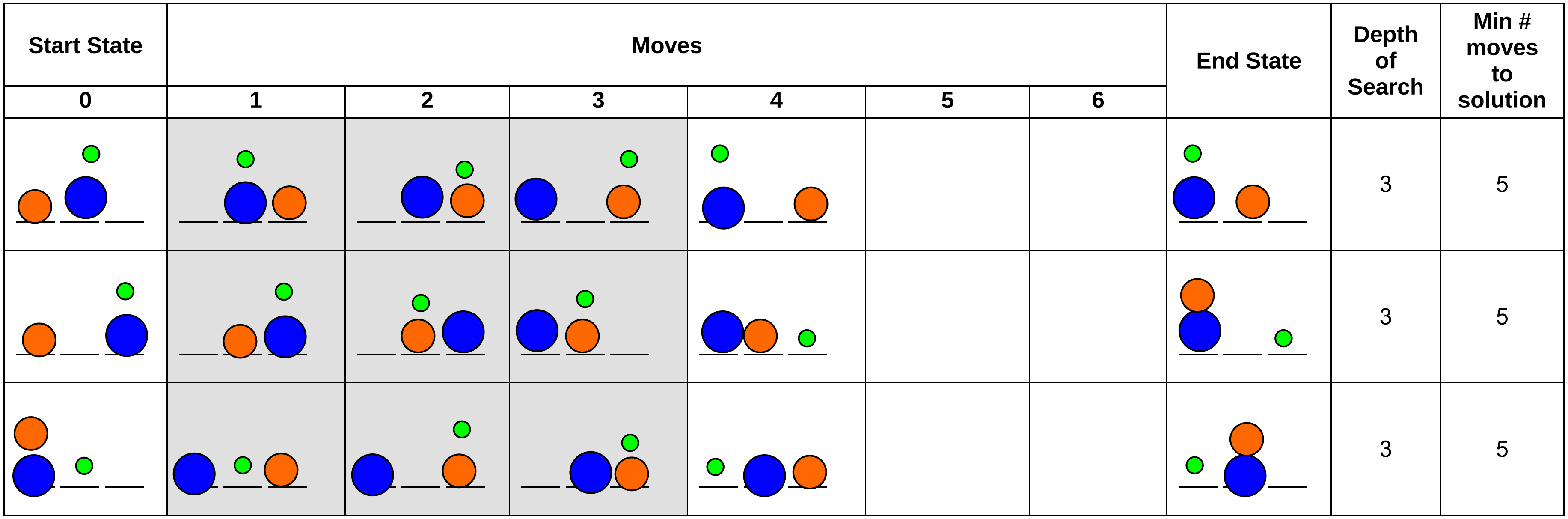


Figure 3. Diagram of Problems Presented in the Reward Phase. All four problems have an equal Depth of Search (DOS = 3) and minimum number of moves to solution (MTS = 5). The shaded ring arrangements correspond to the moves in each problem that define the DOS.

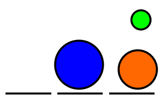
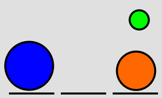
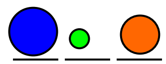
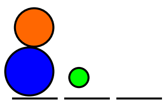
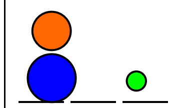
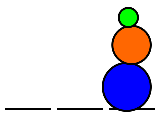
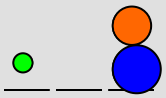
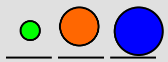
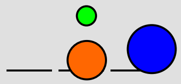
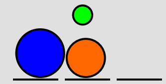
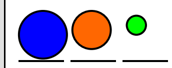
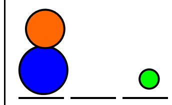
Start State	Moves						End State	Depth of Search	Min # moves to solution
0	1	2	3	4	5	6			
								1	4
								4	6

Figure 4. Diagram of Problems Presented in the Free-choice phase. The problems vary in terms of Depth of Search (DOS) and minimum number of moves to solution (MTS). The shaded ring arrangements correspond to the moves in each problem that define the DOS.

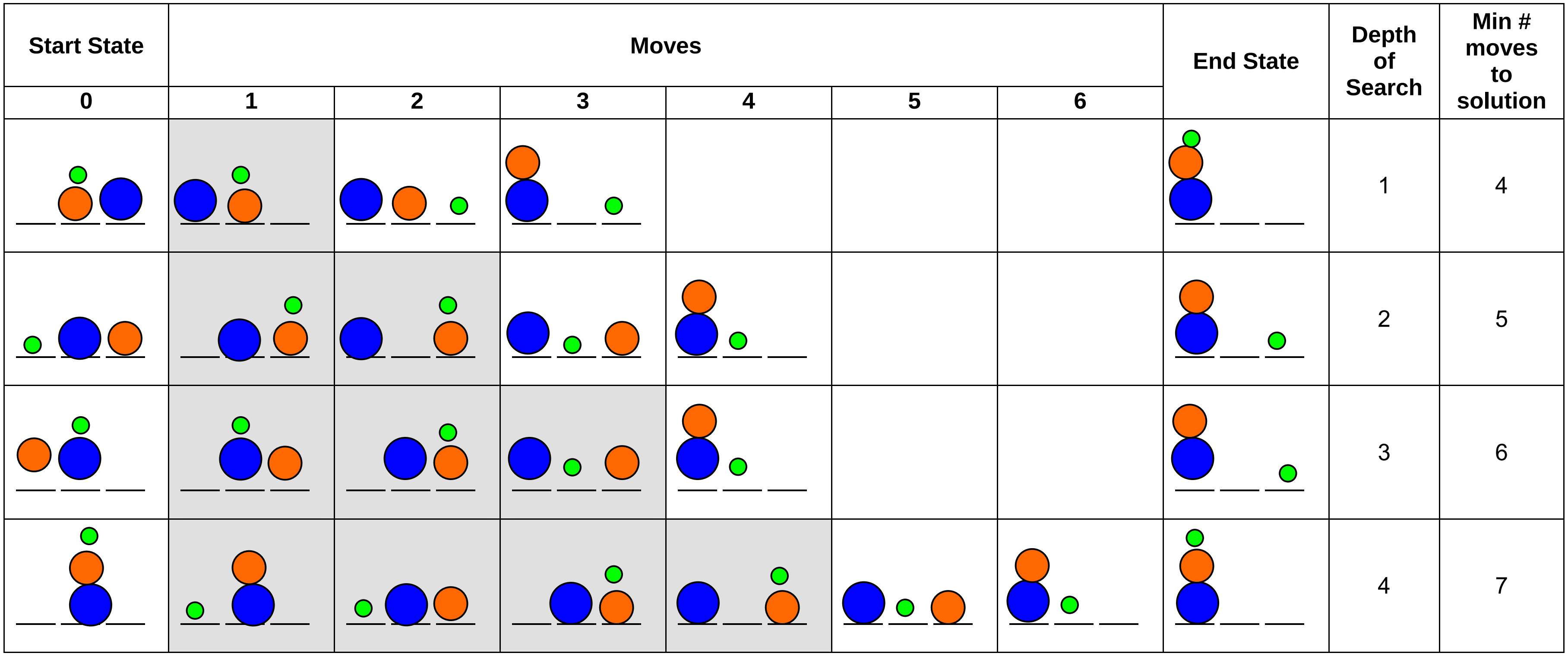


Figure 5. Diagram of the Problems Presented in the Re-evaluation Phase. One of the above problems was selected and presented based upon participants' highest level of performance during the Evaluation phase. The shaded ring arrangements correspond to the moves in each problem that define the DOS.

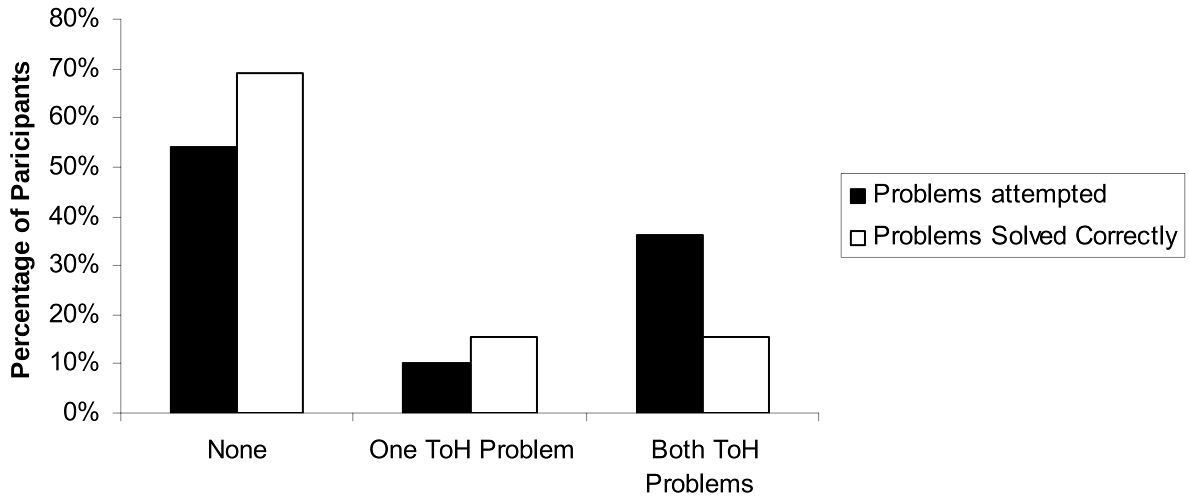


Figure 6. Performance during ToH Free-choice Phase.

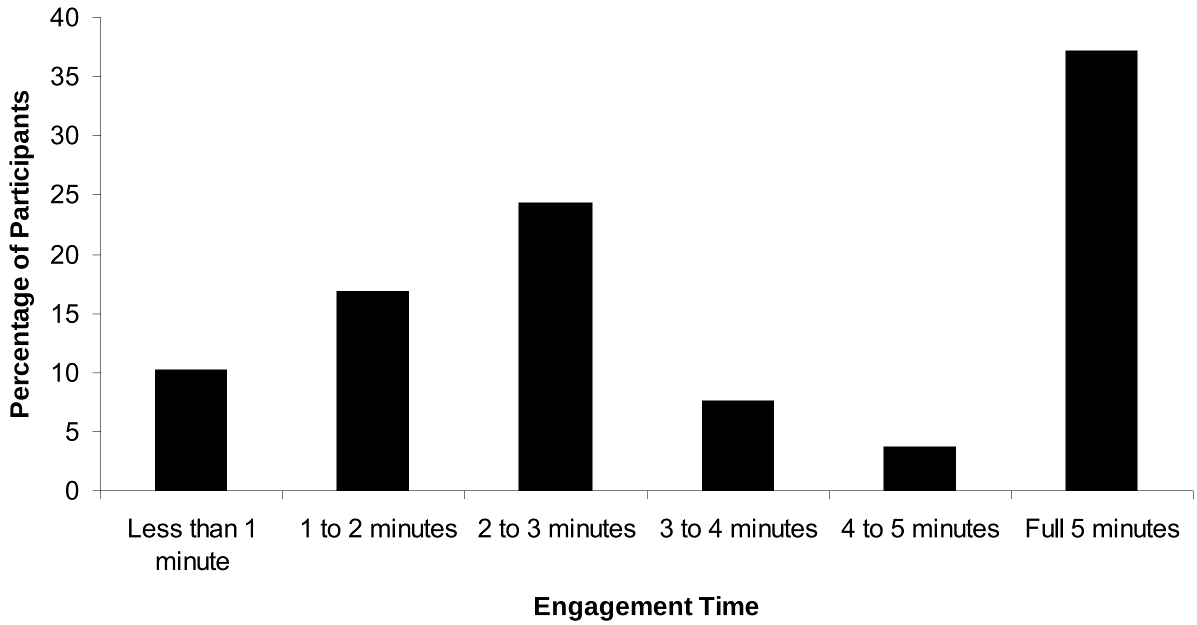


Figure 7. Engagement Time During the TTT.

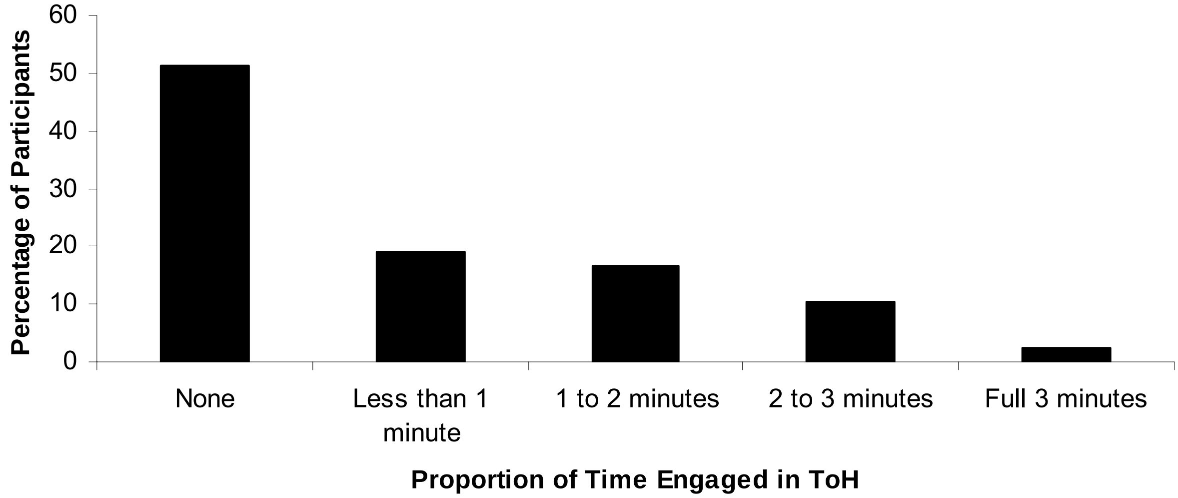


Figure 8. Engagement Time During the ToH.

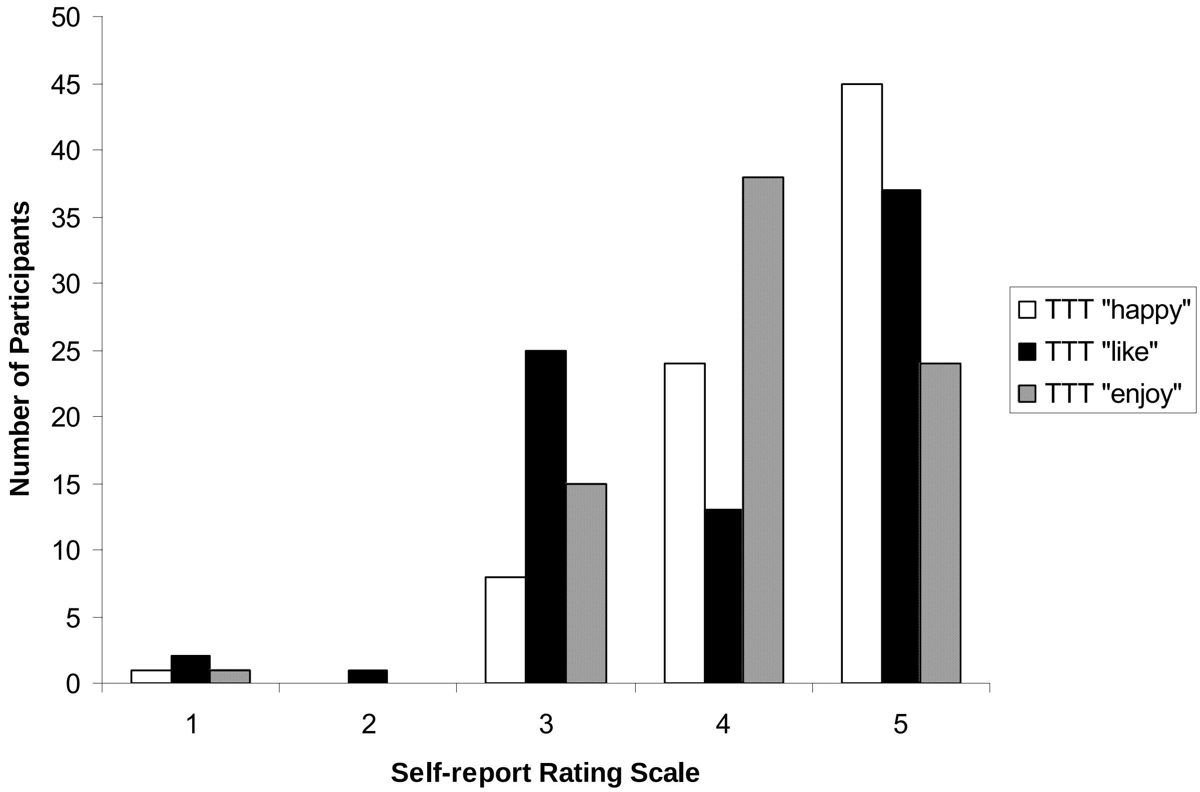


Figure 9. Distribution of Self-report Ratings of Affect for the TTT.

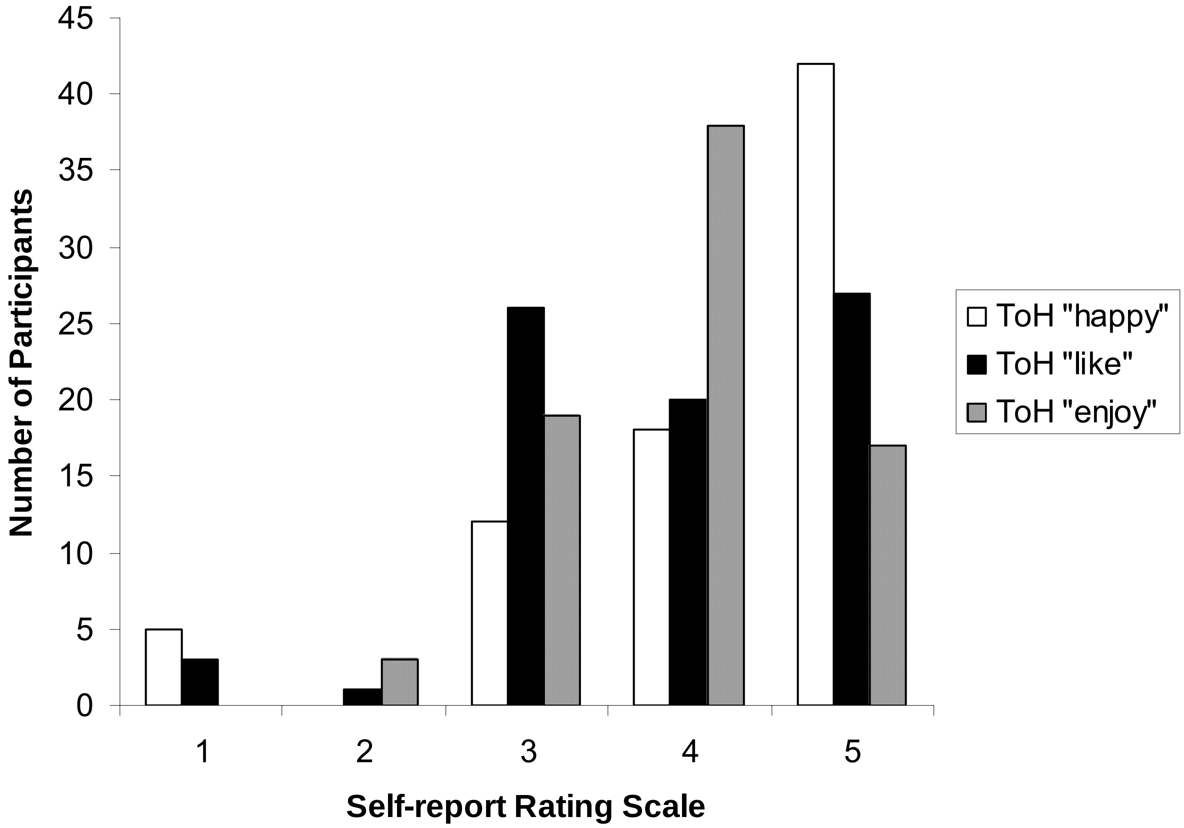


Figure 10. Distribution of Self-report Ratings of Affect for the ToH.

Table 1. Cell counts

	Reward Condition				Total
	Reward		No reward		
	Male	Female	Male	Female	
Younger Age Group (4- to 5-yer-olds)	8	11	10	10	39
Older Age Group (5- to 6-year-olds)	13	7	12	7	39
TOTAL	21	18	22	17	78

Table 2. Items used in the TTT

Wooden Dowels	Wooden Rounds	Others
Green (4)	Wheels (4)	Connectors (6)
Red (4)	Knobs (10)	Caps (6)
Orange (4)		
Yellow (6)		
Blue (6)		

Table 3. Tinkertoy Test Scoring Criteria

Variable	Scoring Criteria	Points
1. mc	Any combination of pieces	1
2. 3d	Symmetric=1, 3-dimensional=1	0-2
3. mov	Mobility=1, moving parts=1	0-2
4. name	Appropriate=3, vague/inappropriate=2, post-hoc naming, description=1, none=0	0-3
5. npieces	*n* < 20 = 1, < 30 = 2, < 40 = 3, < 50 = 4	1-4
6. stand	Free-standing, stays standing=1	1
7. error	For each error (misfit, incomplete fit, drop and not pick up	-1
Highest possible score		13
Lowest possible score		-1 or less

Table 4. Private Speech Content Classification Scheme

Level	Description	Example
Level 1: Off-task	(a) Affect expression (b) Commenting (c) Questioning	"Oh, my hand hurts!"
Level 2: Task-relevant and nonfacilitative	(a) Giving up (b) Questioning	"I'll never get this!" "Why do I need to do this?"
Level 3: Cognitive	(a) Focusing (b) Describing (c) Questioning (d) Directing	"Does this go here or there?" "Put this one right here."
Level 4: Metacognitive	(a) Correcting (b) Coping (c) Reinforcing (d) Solving	"No, not this way!" "Yay! I did it" "I made it match, I'm right!"

Adapted from Manning et al. (1994).

Table 5. Means (and Standard Deviations) for Performance on the TTT

	Mean	Range
TTT Complexity (max =13)	7.34 (1.58)	3 to 11
TTT Dependency Copying	0.49 (3.23)	0 to 28
TTT Dependency Asking	0.76 (1.76)	0 to 13
TTT Dependency Referencing	2.53 (4.39)	0 to 24

Table 6. Correlations between TTT Complexity and Dependency Scores

	1	2	3	4
1. TTT Complexity	-	0.28*	-0.12	0.09
2. TTT Dependency Copying		-	0.34**	0.60**
3. TTT Dependency Asking			-	0.26*
4. TTT Dependency Referencing				-

Note. *p < 0.05; **p < 0.01

Table 7. Means and Standard Deviations for ToH Performance

	Mean (SD)	Range
Evaluation Phase Score	0.47 (0.12)	0.27 to 0.84
Reward Phase Score	0.54 (0.20)	0.25 to 1.00
Free Choice Phase Scores		
Number of Problems Attempted	0.82 (0.94)	0 to 2
Number of Problems Solved Correctly	0.46 (0.75)	0 to 2
Re-evaluation Phase Score	0.83 (0.38)	0 to 1

Table 8. Performance during ToH Free-choice Phase

	Number of Problems Attempted	Number of Problems Solved Correctly
None	54%	69%
One ToH Problem	10%	15.5%
Both ToH Problems	36%	15.5%
TOTAL	100%	100%

Table 9. Summary of Binary Logistic Regression Analysis for Variables Predicting Number of Performance during the ToH Re-evaluation Phase

	B	SE *B*	e^B
Reward Condition	-0.57	0.63	0.57

Note. e^B = exponentiated *B*. The reference category is “Passed ToH Problem”.

Table 10. Correlations between TTT and ToH Performance Scores

	1	2	3	4	5	6	7
1. TTT Complexity	-	.28*	-.12	.09	.-.17	-.18	.08
2. TTT Dependency Copying		-	.34**	.60**	-.09	-.13	.07
3. TTT Dependency Asking			-	.26*	.08	-.16	.04
4. TTT Dependency Referencing				-	.02	-.09	.07
5. ToH Evaluation Phase Score					-	.39**	-.26*
6. ToH Reward Phase Score						-	-.31**
7. ToH Re-evaluation Phase Score							-

Note. $^{\dagger}p < .08$, $^{*}p < .05$, $^{**}p < .01$

Table 11. Means and Standard Deviation of Free Choice Behavior during the TTT and ToH

	Mean (SD)	Range
TTT Enagagement Time	196.1 (94.7)	0 to 300
ToH Engagement Time	0.23 (0.31)	0 to 1.00

Note. TTT Engagement time is in seconds. ToH Engagement time is a proportion score.

Table 12. Means and Standard Deviations for Ratings of Affect

	EF Task	
	TTT	ToH
ToH “Happy Rating	4.44 (0.78)	4.20 (1.12)
ToH “Like” Rating	4.05 (1.04)	3.87 (1.04)
ToH “Enjoy” Rating	4.08 (0.79)	3.90 (0.79)

Note. All Ratings were on a 5-point scale.

Table 13. Means and Standard Deviations for Ratings of Affect for the ToH as a Function of Reward Condition

	Reward Condition	
	Reward (*N* = 39)	No Reward (*N* = 39)
ToH “Happy Rating	4.13 (1.20)	4.26 (1.06)
ToH “Like” Rating	3.85 (1.01)	3.90 (1.09)
ToH “Enjoy” Rating	3.87 (0.86)	3.92 (0.71)

Note. All Ratings were on a 5-point scale.

Table 14. Correlations between TTT and ToH Self-Reports of Motivation

	1	2	3	4	5	6
1. TTT “Happy” Rating	-	-.03	.09	.21†	-.17	.01
2. TTT “Like” Rating		-	.28**	-.15	.20**	.21†
3. TTT “Enjoy” Rating			-	-.12	-.15	.42**
4. ToH “Happy Rating				-	.10	.21
5. ToH “Like” Rating					-	.13
6. ToH “Enjoy” Rating						-

Note. †$p < .07$, *$p < .05$, **$p < .01$

Table 15. Correlations between Free Choice 1st Item touch and Free Choice Duration of Engagement in the ToH and Each of the Self-report Variables (Happy, Like, Enjoy)

	Condition	
	Reward	No Reward
Free-choice engagement time and "Happy"	-.06	.19
Free-choice engagement time and "Like"	.24	-.07
Free-choice engagement time and "Enjoy"	.29†	-.08
Free-choice engagement time and Affect	.38*	-.09
Free-choice 1st item touched and "Happy"	-.04	.08
Free-choice 1st item touched and "Like"	.33*	-.03
Free-choice 1st item touched and "Enjoy"	.36*	.002
Free-choice 1st item touched and Affect	.50**	-.03

Note. † p <.08, * p < .05, ** p < .01. Affect is a sum of the "Like" and "Happy" ratings.

Table 16. Correlations between Motivation and Performance on the TTT

	1	2	3	4	5	6	7	8
1. TTT Construction Time	-	-.09	.08	.00	-.17	.14	.24*	.39**
2. TTT “Happy” Rating		-	-.03	.09	.02	-.17	-.12	-.05
3. TTT “Like” Rating			-	.28**	.18	.01	.06	-.01
4. TTT “Enjoy” Rating				-	.03	.14	-.04	.12
5. TTT Complexity					-	.28*	-0.12	.09
6. TTT Dependency Copying						-	.34**	.60**
7. TTT Dependency Asking							-	.26*
8. TTT Dependency Referencing								-

Note. †p < .07, *p < .05, **p < .01

Table 17. Correlations between Motivation and Performance on the ToH

	1	2	3	4	5	6	7	8
1. ToH Free-Choice engagement time	-	.03	.16	-.14	.06	-.15	.23	.05
2. ToH “Happy” Rating		-	.15	.08	-.16	-.20	.08	.17
3. ToH “Like” Rating			-	.03	-.05	-.30**	-.06	.02
4. ToH “Enjoy” Rating				-	-.12	-.15	.04	.26*
5. ToH Evaluation Phase Score					-	.39**	-.19	-.27*
6. ToH Reward Phase Score						-	-.18	-.30**
7. ToH Free-choice Phase Score							-	.19
8. ToH Re-evaluation Phase Score								-

Note. $^{\dagger}p < .06$, $*p < .05$, $**p < .01$

Table 18. Means and Standard Deviations for Proportion of Level of Private Speech Produced During the TTT and ToH

	Proportion of Level 1 Private Speech	Proportion of Level 2 Private Speech	Proportion of Level 3 Private Speech	Proportion of Level 4 Private Speech
Tinkertoy Test (*N* = 31)	.19 (.31)	.32(.37)	.36 (.36)	.14 (.23)
Tower of Hanoi (*N* = 64)	.02 (.08)	.15(.23)	.65 (.29)	.17 (.24)

Note. The difference in the *n*s reflects how many children elicited private speech in each EF task.

Table 19. Mean Differences (and Standard Error) in Types of Private Speech Produced During ToH

	Mean Difference
Type 1 Private Speech - Type 2 Private Speech	*-.13 (.03)***
Type 1 Private Speech - Type 3 Private Speech	*-.63 (.04)***
Type 1 Private Speech - Type 4 Private Speech	*-.15 (.03)***
Type 2 Private Speech - Type 3 Private Speech	*-.50 (.06)***
Type 2 Private Speech - Type 4 Private Speech	*-.02 (.04)*
Type 3 Private Speech - Type 4 Private Speech	*.48 (.06)***

Note. * $p < .05$, ** $p < .01$. *Differences are between proportions of each type of private speech*

.

Table 20. Correlations between Amount and Level of Private Speech on the EF Tasks

	Tinkertoy Test					Tower of Hanoi				
	1	2	3	4	5	6	7	8	9	10
Tinkertoy Test										
1. Total Number of PS Utterances	-	-.21	.17	-.03	.07	.43**	-.02	-.04	.02	.01
2. Proportion of PS L1 (Off-task)		-	-.39**	-.35†	-.19	-.21	-.11	-.09	.26	-.22
3. Proportion of PS L2 (Non-facilitative)			-	-.54**	-.25	-.08	.18	.16	-.27	.16
4. Proportion of PS L3 (Cognitive)				-	-.23	.22	-.04	.00	.07	-0.5
5. Proportion of PS L4 (Metacognitive)					-	.08	-.09	-.15	.00	.09
Tower of Hanoi										
6. Total Number of PS Utterances						-	-.08	-.15	.26*	-.13
7. Proportion of PS L1 (Off-task)							-	-.16	-.03	-.15
8. Proportion of PS L2 (Non-facilitative)								-	-.58**	-.18
9. Proportion of PS L3 (Cognitive)									-	-.64**
10. Proportion of PS L4 (Metacognitive)										-

Note. †p < .06, *p < .05, **p < .01

Table 21. Correlations between TTT Performance and Amount and Level of Private Speech

	1	2	3	4	5	6	7	8	9
1. TTT Complexity	-	.28*	-.12	.09	.19	-.51**	.06	.36*	.03
2. TTT Dependency Copying		-	.34**	.60**	.02	-.13	-.17	.35†	-.08
3. TTT Dependency Asking			-	.26*	.10	.32	-.10	-.05	-.19
4. TTT Dependency Referencing				-	.08	-.07	-.08	.15	-.01
5. TTT Total Number of PS Utterances					-	-.21	.17	-.03	.07
6. TTT Proportion of PS L1 (Off-task)						-	-.39**	-.35†	-.19
7. TTT Proportion of PS L2 (Non-facilitative)							-	-.54**	-.25
8. TTT Proportion of PS L3 (Cognitive)								-	-.23
9. TTT Proportion of PS L4 (Metacognitive)									-

Note. †$p < .06$, *$p < .05$, **$p < .01$

Table 22. Correlations between ToH Performance and Amount and Level of Private Speech

	1	2	3	4	5	6	7	8	9
1. ToH Evaluation Phase Score	-	.39**	-.19	-.27*	-.11	.11	.02	.11	-.16
2. ToH Reward Phase Score		-	-.18	-.31*	.02	.18	.08	.14	-.27*
3. ToH Free-choice Phase Score			-	.19	-.01	.02	-.20	.10	.00
4. ToH Re-evaluation Phase Score				-	.14	-.16	.04	.01	-.01
5. ToH Total Number of PS Utterances					-	-.08	-.15	.26*	-.13
6. ToH Proportion of PS L1 (Off-task)						-	-.16	-.03	-.15
7. ToH Proportion of PS L2 (Non-facilitative)							-	-.58**	-.18
8. ToH Proportion of PS L3 (Cognitive)								-	-.64**
9. ToH Proportion of PS L4 (Metacognitive)									-

Note. †$p < .06$, *$p < .05$, **$p < .01$

Table 23. Correlations between Measures of Motivation and Amount and Level of Private Speech on the EF Tasks

	Tinkertoy Test							Tower of Hanoi						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Tinkertoy Test														
1. Construction Time	-	.06	.20†	.29	.18	-.26	-.26	.11	.09	-.19	.15	.04	-.14	.10
2. Ratings of affect		-	-.04	-.10	.16	-.15	.10	.08	.32**	-.30**	-.10	.03	-.04	.02
3. Total Number of PS Utterances			-	-.21	.17	-.03	.07	.02	.25*	.43**	-.02	-.04	.02	.01
4. Proportion of PS L1 (Off-task)				-	-.39**	-.35†	-.19	.19	-.43*	-.21	-.11	-.09	.26	-.22
5. Proportion of PS L2 (Non-facilitative)					-	-.54**	-.25	-.40*	.12	-.08	.18	.16	-.27	.16
6. Proportion of PS L3 (Cognitive)						-	-.23	.21	.17	.22	-.04	.00	.07	-0.5
7. Proportion of PS L4 (Metacognitive)							-	.06	.11	.08	-.09	-.15	.00	.09
Tower of Hanoi														
8. Free-choice engagement time								-	.15	.13	-.14	-.31*	.16	.14
9. Ratings of affect									-	-.14	-.21	-.01	-.18	.25*
10. Total Number of PS Utterances										-	-.08	-.15	.26*	-.13
11. Proportion of PS L1 (Off-task)											-	-.16	-.03	-.15
12. Proportion of PS L2 (Non-facilitative)												-	-.58**	-.18
13. Proportion of PS L3 (Cognitive)													-	-.64**
14. Proportion of PS L4 (Metacognitive)														-

Note. †*p* < .08, **p* < .05, ***p* < .01. Construct Time is a log transformation of the time children spent constructing during TTT. "Ratings of affect" is a sum of the "Like" and "Happy" ratings for each EF task.

Table 24. Correlations between WPPSI Scores

	1	2	3
1. WPPSI Block Design	-	.24*	.26*
2. WPPSI Vocabulary		-	.49**
3. WPPSI Receptive Vocabulary			-

Note. †$p < .06$, *$p < .05$, **$p < .01$.

Table 25. Summary of Regression Analyses for Establishing Mediation

Step in Establishing Mediation	Criterion Variable	Predictor Variable(s)	B^a	t	R^2	Df	F
1	TTT Dependency Asking	TTT Construction Time	.24	2.16	.06	1, 77	4.67**
1	TTT Dependency Referencing	TTT Construction Time	.39	3.71	.15	1, 76	13.77**
1	ToH Reward Phase Score	ToH “Like” Rating	-.30	-2.73	.09	1, 76	7.45**
1	ToH Reward Phase Score	ToH Affect Rating	-.33	-2.99	.11	1, 76	8.95**
1	ToH Re-evaluation Phase Score	ToH “Enjoy’ Rating	.26	2.36	.07	1, 76	5.58*
2	ToH Proportion PS L2 (Non-facilitative)	ToH Free-choice Engagement Time	-.31	-2.55	.10	1, 63	6.48*
2	ToH Proportion PS L4 (Metacognitive)	ToH Affect Rating	.25	2.00	.06	1, 62	4.01*
3	ToH Reward Phase Score	ToH Affect Rating	-.34	-2.84	.18	2, 62	6.52**
		ToH Proportion PS L4 (Metacognitive)	-.18	-1.45			

Note. [a] β values are standardized; * $p < .05$; ** $p < .01$, Overall $N = 78$.